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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, Director

GEOLOGY AND MINERAL RESOURCES

OF PART OF THE

CUMBERLAND GAP COAL FIELD, KENTUCKY

BY

GEORGE HALL ASHLEY AND LEONIDAS CHALMERS GLENN

IN COOPERATION WITH THE STATE GEOLOGICAL DEPARTMENT OF KENTUCKY
C. J. NORWOOD, Curator

WASHINGTON
GOVERNMENT PRINTING OFFICE
1906

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The coal.—The development of the coal is confined to the western part of the field studied, mainly to the west of Middlesboro, in Claiborne County, Tenn. In that part of the field exploration has shown thirteen coals of workable thickness and quality. Of these, eight coal beds at present are commercially mined. These vary in thickness from 4 to 6 feet. Nearly all of these beds have one or more partings. The coal of the eastern part of the field has been little tested, and knowledge of it is derived largely from natural exposures, a few small country banks, and a small number of facings. In the eastern part of the field, around Harlan, one coal with a thickness of about 4 feet has been shown to have an area of probably 100 square miles. Above this are usually from one to three other coals, which are locally workable, and may be worked over a large area in that part of the district. Between the Harlan district and the Middlesboro district from one to three workable coals underlie most of the area. The Harlan coal as a rule is not as badly split up with partings as the coals above Middlesboro. In quality these coals compare well with the Westmoreland gas coals of Pennsylvania. Some of the coals at Middlesboro are successfully coked, and doubtless most of the coals of this area are of the same character. In percentage of moisture, ash, and sulphur these coals show a purity equal to probably the best of the Appalachian coals.

Exploitation and development.—Development in this region has been going on since about 1892, as previous to that time there were no railroad connections. Now the field is connected with Louisville and Cincinnati by the Cumberland Valley Branch of the Louisville and Nashville, and with Knoxville by the Southern Railway. The output has grown until it reaches from 600,000 to 1,000,000 tons a year. Its nearness to the iron-ore beds of Virginia and Tennessee has led to the establishment of a blast furnace at Middlesboro; and as a result of the cheapness of fuel and the presence of the raw material other industries have rapidly sprung up. The larger portion of this field is as yet without railroad connections, but present indications are that the Southern may soon build a branch road up the Cumberland River to Harlan, allowing the development of the eastern part of the field, while railroads now building will open up the portion of the field in Campbell County, Tenn., in 1905 or immediately thereafter.

GEOLOGY AND MINERAL RESOURCES OF A PART OF THE CUMBERLAND GAP COAL FIELD. KENTUCKY.

By G. H. Ashley and L. C. Glenn.

INTRODUCTION.

LOCATION OF FIELD.

The Cumberland Gap coal field lies in Bell and Harlan counties, in the southeast corner of Kentucky and in Claiborne and Campbell counties, Tenn., and extends in a general northeast-southwest direction between Pine and Cumberland mountains from Fork Mountain on the southwest to the heads of Poor and Clover forks of Cumberland River on the northeast. As defined in this paper, it has a total length of about 90 miles and a width of from 15 to 20 miles. (See Pl. II.)

In this paper is described only the central part of the basin, or the area lying between Log Mountains at the head of Yellow Creek of Cumberland and a nearly north-south line about 10 miles east of Harlan, and while the data presented will give an idea of the general stratigraphy and structure of the whole field, they are not authoritative except within these limits.

FIELD WORK.

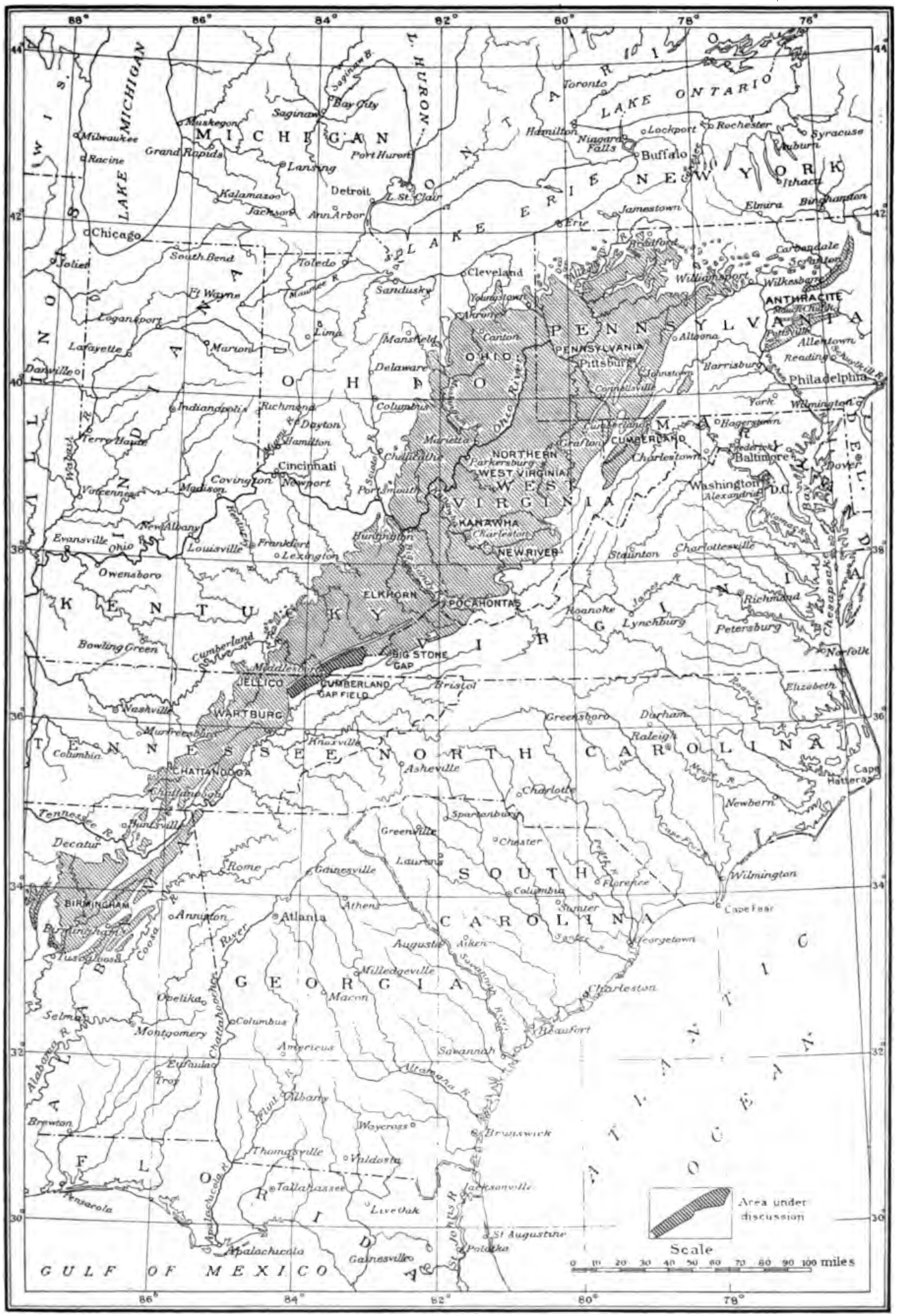
Field work for this report began July 1, 1902, and continued until September 20, 1902. The field party consisted of G. H. Ashley and L. C. Glenn, geologists; H. Nowell, topographic aid; G. C. Marsh, photographer; and, during August, T. W. Sprague, who took charge of the coal sampling. The geologic work was planned so that Mr. Glenn gave especial attention to the stratigraphic and areal geology, while Mr. Ashley obtained most of the data about the coals. It was intended at that time that Mr. Glenn should write the sections on stratigraphy, structure, and correlations, while Mr. Ashley wrote the sections on the general description, topography, general geology, and coal resources. After a small amount of preliminary work on the notes had been done by Messrs. Glenn and Ashley a change in plans made it necessary for the latter to prepare the whole report. The field work showed the inadequacy of the old reconnaissance topographic map which had served as a base for the geologic work, and it was decided to prepare new topographic maps of those quadrangles included in the portion of the basin studied by the geologists, to be on the scale of 1 inch to the mile and to have 20-foot contours. A large party was placed in the field, and an attempt was made to run at least stadia lines up all streams over half a mile long and along all the principal crests, making the work of unusually high grade for this type of country.

The topographic work was in charge of Nathaniel Tyler, jr., who was assisted by R. W. Berry, Will Ward Duffield, and C. E. Pearce. The ruggedness and densely wooded condition of the area rendered the work slower than had been anticipated, so that the allotment was exhausted before the portions of the quadrangles outside of the basin could be completed, or even all of the area in the basin that was studied geologically. Some work was done on the portion of the basin in the Log Mountain quadrangle west of the Middlesboro quadrangle, but not enough to make possible the preparation of a satisfactory topographic map. Accordingly, the data obtained by Mr. Nowell in 1902 and very valuable maps kindly furnished by the Louisville Property Company and the American Association Incorporated have been combined with the data obtained in 1903 to make the sketch map of the Log Mountains district.

In a region as heavily timbered as this the topographic sketching must, to a large degree, be approximate only; so that a comparison of the locations and elevations of the coal outcrops on the maps, with the statements concerning the same in the text will be found in a few cases to show a disagreement. This is most noticeable where the locations and elevations of the coals have been determined instrumentally, either by stadia or transit, since the drawing of the map. In cases of such disagreement a compromise has often been necessary in showing the location of a coal on the map, though usually the attempt was made to show its horizontal position rather than its position relative to the surface contours, as it is believed that such procedure would best meet the needs of the engineer in the field.

In September, 1903, Mr. David White spent about ten days in this basin and collected fossils which not only formed the basis of most of the correlations in the chapter on that subject, but in several cases assisted materially in correlating or differentiating coals at different points in the basin. During the topographic work in 1903, Mr. Sprague obtained samples at a number of additional openings and at a number of points omitted the preceding year. In some cases he had old openings reopened. For a month from September 20, 1903, Mr. Ashley, accompanied by Mr. Sprague, made a rapid reconnaissance trip over the basin, getting additional data and attempting to locate the lines of traverse run in the season of 1902. To have done this fully would have meant almost an entire retracing of the first year's work, for which there was not time.

While many favors were shown in all parts of the field, special acknowledgment is due to Mr. Robert Creech, who at different times spent several days piloting the writer to facings being made under his direction, and to other points where valuable coal data were obtained; to Mr. T. Cairns, of the Louisville Property Company, who supplied maps and sections of the land and coals on the Louisville Property Company's lands; to Mr. J. H. Bartlett and Mr. J. C. Richardson of the American Association Incorporated, for similar data concerning their lands, and to Mr. Charles Henry Davis, trustee of the Davis estate, who placed in our hands all of the large mass of information they possessed concerning the area of that estate. Thanks



MAP SHOWING POSITION AND RELATIONS OF CUMBERLAND GAP COAL FIELD.

are due to these and to the many others who gave freely of their time and information. Finally Mr. Sprague, in addition to the work mentioned above, gathered a large amount of valuable geologic data, and to him is due in no small degree the accuracy and completeness of the report.

This work was carried on in cooperation with the State of Kentucky, as represented by the curator of the State geological department, Mr. C. J. Norwood. Mr. Norwood determined the area to be surveyed and supplied approximately one-half of the necessary funds. The work was done by the United States Geological Survey in accordance with its usual method.

The photographs from which the half-tone plates accompanying this report were made were kindly loaned by Mr. Charles Henry Davis.

LITERATURE.

The following reports are those most frequently referred to:

McCREATH and d'INVILLIERS. Resources of the Upper Cumberland Valley, southeastern Kentucky, and southwestern Virginia, tributary to the proposed Cumberland Valley extension of the Louisville and Nashville Railroad. Louisville, Ky., 1888.

The area described in this paper includes that covered in 1902, but extends some distance farther to the northeast along the same synclinal basin. The paper gives detailed sections of the coals at a large number of points, and analyses of the coals from samples properly obtained. It has, therefore, been frequently referred to, especially for the analyses. Most of the coal sections given in the above-mentioned report were measured independently during the present work, and the figures correspond to such a degree as to give the highest confidence in the correctness of the sections that could not be found or measured.

ANNUAL REPORTS OF THE INSPECTOR OF MINES OF THE STATE OF KENTUCKY.

Especially the report for 1901-2, which repeats or abstracts most of the geologic data given in the preceding volumes.

GEOLOGICAL SURVEY OF KENTUCKY, Chemical Analyses, A, Parts I, II, III.

Many analyses of coals of this field were obtained from these reports. All these analyses are of air-dried samples, and little is known of the method of obtaining samples. In some cases it is known that they were averaged.

REPORT OF PROF. JOHN R. PROCTER, DIRECTOR OF GEOLOGICAL SURVEY OF KENTUCKY, April 20, 1893.

Mainly copies of sections and analyses of coals measured by Mr. R. C. Ballard Thruston, and by McCreath and d'Invilliers, in the report quoted above, in Bell and Harlan counties.

A. R. CRANDALL. Reports to Log Mountain Coal, Coke, and Timber Company, American Association Incorporated, and Southern Land Improvement Company.

Extracts of some of these reports have already been published in the mine inspector's reports, especially those for 1893 and 1901-2. In other cases the full reports were kindly placed at our disposal by the companies to whom they were made.

T. CAIRNS, MANAGER OF THE LOUISVILLE PROPERTY COMPANY (successors to Log Mountain Coal, Coke, and Timber Company).

REPORT OF R. H. ELLIOTT ON LOG MOUNTAIN COKE, published by Log Mountain Coal, Coke, and Timber Company.

REPORT OF MR. G. D. FITZHUGH TO THE SAME COMPANY.

In addition to coals examined by the geologists of the party, and those described in the above reports, many coals were seen by the topographers in 1903, or by the members of the party who visited selected openings and obtained properly averaged samples for analyses. On account of differences in barometric readings and lack of full reports on the rocks immediately above and below, it was often difficult to assign such coals to their proper stratigraphic horizons.

GEOGRAPHY.

GENERAL PHYSIOGRAPHY.

PHYSIOGRAPHIC RELATION.

In order to understand the physiography of the Cumberland Gap area, it is necessary to consider briefly and in a broad way the physiography of the general region of which it is a part. The highland of the eastern United States lying between the Atlantic Coastal Plain and the lowlands of the Mississippi Valley, known as the Appalachian province, may be subdivided into three well-marked physiographic divisions. On the east are the Appalachian Mountains, extending in irregular ranges from southern New York to central Alabama. West of these is the Appalachian Valley. It is 40 to 125 miles wide and is somewhat lower than the mountainous region on either side. It extends from the Coosa Valley, in Georgia and Alabama, to the Lebanon Valley, in northeastern Pennsylvania. Near Middlesboro it is known as the Great Valley of East Tennessee and Virginia. The third or western division, which includes the Middlesboro coal field, is a high upland which on the east is bordered by a regular and marked escarpment facing the Great Valley and on the west often merges into the lowlands through a belt of foothills. This division includes the Cumberland Plateau at the south and the Allegheny Mountains at the north. (See fig. 1.)

FACTORS CONTROLLING PHYSIOGRAPHY.

The factors controlling the physiography of this province are varying hardness of the rocks, the arched structure, and a series of broad earth movements.

The different physiographic divisions are composed of rocks of various degrees of hardness. The Appalachian Mountains contain hard rocks resisting weathering, while the Great Valley is underlain by many limestones which yield readily to erosion. The Allegheny Mountains and Cumberland Plateau consist mainly of the sandstones and accompanying shales of the Pennsylvanian series, the first of which yield but slowly to erosion.

The Appalachian province represents the northwestern limb of a high arch into which the rocks of the eastern United States were thrown by mountain-making forces. In the center of this arch the rocks are closely folded and faulted, but toward the west the folds and faults become less intense, and almost the ast of them are seen in Cumberland and Pine mountains. This arch and the minor folding has determined the position and elevation of the rocks, and thus their exposure to erosion.

A third factor has been the series of broad earth movements by which the province was elevated at different times after it had been planed down by erosion to a more or less even surface, or peneplain. Three such levels of erosion have been recognized by Hayes and Campbell in the southern Appalachians. Of these only the oldest and highest is represented in the Cumberland Gap coal field

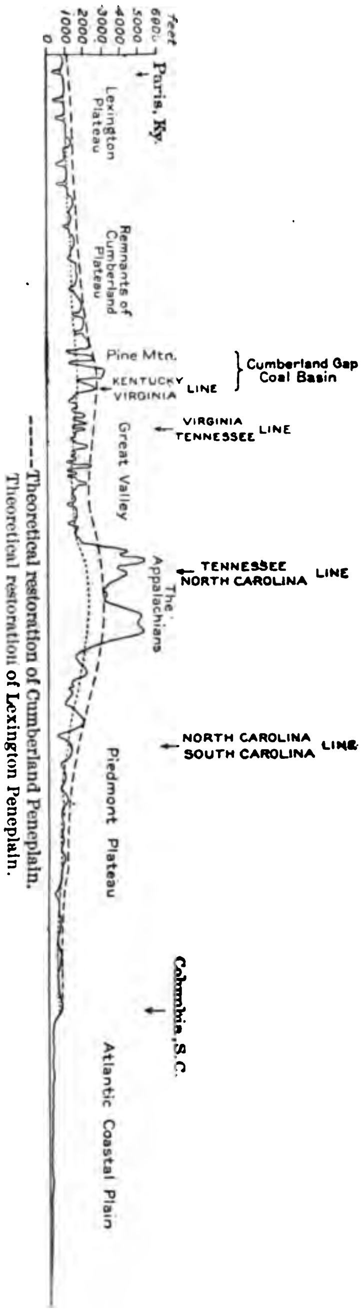

feet
6000
5000
4000
3000
2000
1000
0
Paris, Ky.
Lexington Plateau
Remnants of Cumberland Plateau
Pine Mtn.
Cumberland Gap Coal Basin
KENTUCKY VIRGINIA LINE
VIRGINIA TENNESSEE LINE
Great Valley
The Appalachians
TENNESSEE NORTH CAROLINA LINE
Piedmont Plateau
NORTH CAROLINA SOUTH CAROLINA LINE
Columbia, S.C.
Atlantic Coastal Plain
----Theoretical restoration of Cumberland Peneplain.
Theoretical restoration of Lexington Peneplain.

FIG. 1.—Topographic profile across Appalachian Highland. Scale, approximately 75 miles to the inch.

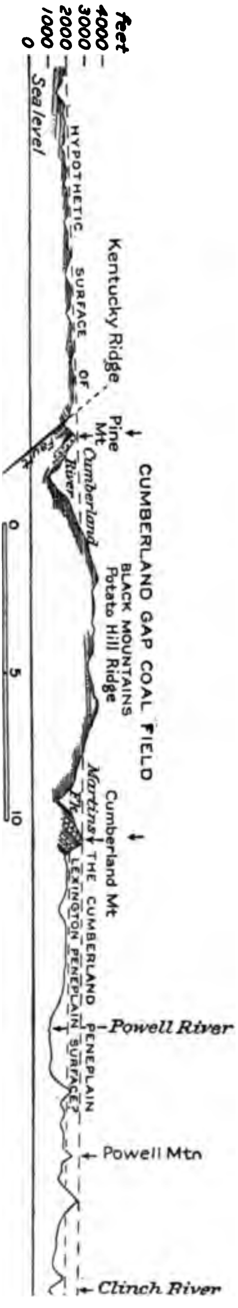


FIG. 2.—Enlargement of part of profile shown in fig. 1.

This peneplain, of which the Cumberland Plateau of Tennessee is a remnant, is thought to have been of late Cretaceous age. It was first called the Schooley peneplain, from Schooley Mountain, New Jersey, and in Tennessee and Kentucky it has been termed the Cumberland peneplain. Below it another erosion level has been developed, which Mr. Campbell, in the London folio, called the Lexington peneplain.

North of Pine Mountain all the hilltops lie in the same plane and thus in a limited area rise to about the same elevation. Forty miles north of Pine Mountain they are about 1,500 feet above tide; to the south the elevation gradually increases until just north of Pine Mountain the divides have an altitude of over 2,400 feet. The plane of the hilltops passes just above Pine Mountain, but apparently not above the Black Mountains. (See fig. 2.) Evidently, then, the tops of the Black Mountain ridges and part at least of Cumberland Mountain remained above the Cumberland peneplain as unreduced residuals. No physiographic traces of the Cumberland peneplain were detected in the Black Mountains.

From any point in the Log Mountains or Black Mountains 100 feet above the summit of Pine Mountain, where an extensive view northward can be obtained, the line of the horizon is seen to be nearly as level as a plain; Pine Mountain, though now eroded until it has a sharp sawtooth crest, is quite level in general elevation. In the center of the Cumberland Gap basin the mountain tops show no signs of having been reduced to a peneplain, nor do they show benches or other evidence of partial reduction, such as might be expected.

Figs. 1 and 2 are cross sections from northwest to southeast through the Appalachian province, showing the three topographic divisions and the positions of the two peneplains.

ALTITUDE OF THE APPALACHIAN PROVINCE.

The southern Appalachian province has an altitude of about 500 feet at its borders and rises in an elongated dome culminating in the crest of the Appalachian Mountains, which have a maximum elevation of over 6,600 feet in western North Carolina. The plateau division is 500 feet above sea at its southern edge and rises to over 2,500 feet in the Cumberland Gap area.

DRAINAGE OF THE APPALACHIAN PROVINCE.

In the northern part of the province the drainage is almost entirely to the Atlantic; farther south it is westward to the Ohio by the New or Kanawha River, which flows through the Cumberland Plateau. Still farther south the drainage of the eastern side of the Appalachian Mountains is eastward to the Atlantic. A part of the Cumberland Plateau is drained by the Cumberland, Kentucky, and other rivers, which flow into the Ohio. The Great Valley for some distance south of New River is drained southward by the Tennessee River, which leaves the valley at Chattanooga and cuts its way through the plateau northwestward to the Ohio. The southern end of the Great Valley is drained southward by the Coosa River, which flows into the Gulf of Mexico.

ORIGIN OF DRAINAGE.[a]

There is room here for only the barest mention of this subject, which is of special interest because of its relation to the origin of the water gap at Pineville and other features in the Cumberland Gap area. Whatever the original direction of the drainage that developed after the great uplift of the Appalachian province, it seems probable that before the end of the long period of erosion resulting in the Cumberland peneplain the central part of the Appalachian province was drained northwestward toward the Ohio Valley. It has been thought that New River and many of the eastern tributaries of the Tennessee are parts of the old drainage system that have persisted. It has been suggested that a stream, of which the French Broad River of western North Carolina may have been one of the head tributaries, rose in the eastern Appalachian Mountains and flowed northwestward toward the Ohio, crossing the eastern part of what is now the Cumberland Plateau in the vicinity of Pineville. After the uplift of this province this northwestward drainage persisted for a time and the streams cut their channels through the hard beds of sandstone which ran transverse to their courses. At the time of that uplift the land sloped as a more or less irregular plain from the western face of the Appalachian Mountains toward the Ohio Valley. The Appalachian Valley and the smaller valleys, such as the Cumberland Valley above Pineville had not been eroded. In this way a notch was cut in the sandstones of Pine Mountain, and probably another one across the Cumberland Mountains, possibly at Cumberland Gap. These notches were first parts of the continuous river channel. That a main line of drainage crossed here for some time is strongly suggested by the fact that from Cumberland Gap to Pineville the mountains for several miles on either side of this line have been reduced to elevations of about 2,000 feet or less above tide—that is, 500 feet or more below the level of the peneplain. A similar reduction occurs north of Pine Mountain. As the uplift seems to have been less at the southern end and along the northwest side of the province, the streams flowing southward into the Gulf of Mexico were brought into competition for the drainage west of the Appalachian Mountains with the northwestward-flowing streams already in possession. The Gulf streams had two advantages over the others, (1) shorter courses, which gave them steeper gradient and greater eroding power, and (2) the fact that they could work back along the outcrops of the easily eroded limestones without being retarded by having to cut through hard sandstones. The result was that the Coosa gradually eroded its channel through the belt of limestones, cutting out what is now the Great Valley and beheading the northwestward-flowing streams one after another until the drainage of all the western flank of the Appalachian Mountains nearly or quite to the New River had been turned to the Gulf of Mexico direct. Later land movements below Chattanooga raised a barrier across the course of this southward drainage and ponded the upper waters. This gave one of the old westward-flowing streams time to cut down its channel across the plateau and to tap the drainage waters of the Great Valley and to divert them to the Mississippi or to the Ohio. In so doing the diverting stream may have regained most of its old head streams as well as all the drainage captured by the stream that had flowed to the Gulf. The two became the Tennessee River of to-day. Meanwhile the pre-Cumberland River, below where it crossed the Cumberland Mountain, continued to deepen its channel into the raised surface of the plateau, though its energy was less because it had lost its headwaters. Gradually its transverse tributaries cut long northeast-southwest valleys in the more easily erodible shales, and, being able to more than keep pace with the main stream in its slow cutting across the hard conglomerate at Pineville, widened their valleys and finally a side tributary from the northeast became the trunk stream. This stream runs in a comparatively broad, flat valley, while the modified river is still slowly lowering its channel through the conglomerate which forms the long sharp ridge of Pine Mountain.

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[a] The discussion of certain features of the relief of this basin is made more complete than is usually the case in an economic paper. This is because it is now uncertain when the topographic surveys will be completed so as to allow the preparation and publication of the geologic folios. The matter could not well be presented in separate form or in the geological journals without considerable expense in republication of the maps.

LOCAL PHYSIOGRAPHY.

SUMMIT TOPOGRAPHY.

The Cumberland Gap coal field lies entirely in the Cumberland Plateau, being bordered on the east by the escarpment, which limits the plateau in that direction. On the northwest it is also bounded by a topographic feature of as great or greater regularity, the long straight ridge known as Pine Mountain. This ridge was formed by the upturning of the massive basal sandstone in connection with Pine Mountain fault. Pine Mountain seems to have been nearly or quite reduced to the level of the Cumberland peneplain. Parts of Cumberland Mountain also seem to have been reduced to the level of the peneplain, while other parts, as the "Butts of the White Rocks," where the summit reaches an elevation of over 3,400 feet, probably escaped reduction. All the higher parts of Black Mountains seem to have remained unreduced.

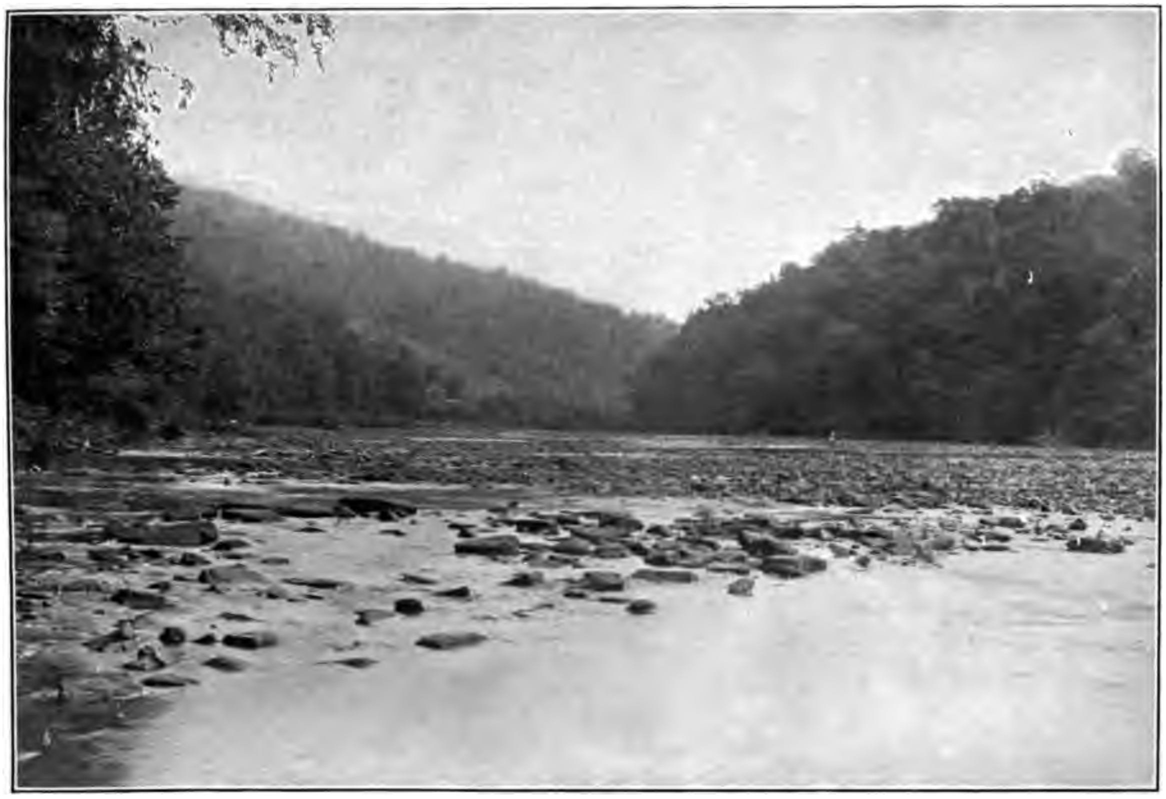
Erosion has worn down the tops of the Black Mountains until they have usually only narrow, irregular crests, some hard sandstone sometimes tending to produce a certain uniformity in the higher parts of a ridge for a short distance. The cross profiles of these crests are in the main those common to areas of horizontal rocks in which the drainage is thoroughly adjusted—that is, the crests are of such a shape that the streams flowing in either direction have equal erosive power, and therefore tend simply to lower them rather than to push them one way or the other. Notable exceptions are those ridges, as Pine and Cumberland mountains, which are due to the upturning of the hard sandstone. In the Cumberland Mountain the streams on the escarpment face have a great advantage and the crest is gradually being moved toward the northwest. It is quite possible that the divides at some of the low gaps are shifting in such a way that future stream adjustments will occur. For instance, it seems probable that Brownies Creek will ultimately tap Martins Fork and divert its headwaters. Still more remotely it seems possible that Falling Water Creek, which flows through Falling Water Gap, may cut down the divide and tap the headwaters of both Martins Fork of Cumberland and called here to the fact that between Cumberland Gap and Chadwell Gap the Cumberland scarp lies well to the northwest of its line of general trend. Along this stretch the longitudinal valleys at the north foot of the mountain are also thrown well to the north. As shown in the section on structure, this position of the mountain is associated with the differential yielding to the southeast-northwest stresses that produced the Cumberland Gap fault, probably the Rocky Face fault, and the close folding around Middlesboro.

VALLEY TOPOGRAPHY.

With some exceptions to be noted later, the topography of the valleys of the Cumberland Gap region is uniformly of two types—one found east and the other west of a line from Pineville to Cumberland Gap. The drainage of the area mapped leaves this basin at the gap at Pineville, where the stream has cut through the resistant sandstones and conglomerates forming Pine Mountain; above Pineville the valleys are mainly cut through shales or comparatively thin sandstones. As a result the streams of the main valleys east of the gap at Pineville are able not only to grade their channels down to where vertical cutting became nominal, but also to erode sidewise so as to widen their valleys or to build up flood plains of often considerable extent. Above the level of this gradient, the streams and their tributaries are actively cutting down their channels and the valleys as a rule are narrowly V-shaped. The accompanying figures showing profile and cross sections of one of the streams will give a good idea of this type. These streams are poorly adapted to the purpose of supplying water power, most of the fall coming immediately at the head where the volume is small. Two exceptions to this type of valley are the headwaters of Martins and Shillaly forks. Both of these rise on Cumberland Mountain where its summit is composed of nearly horizontal beds, and flow for some distance parallel to its crest. Shillaly Fork has only partly trenched into the sandstones of the summit of the mountain, when, having gained some volume, it turns and escapes through a gap along a fault to the valley of Clear Fork of Yellow Creek, descending through the gap in a comparatively short distance over 1,000 feet. The fall of Martins Fork is more regular and is distributed over several miles.

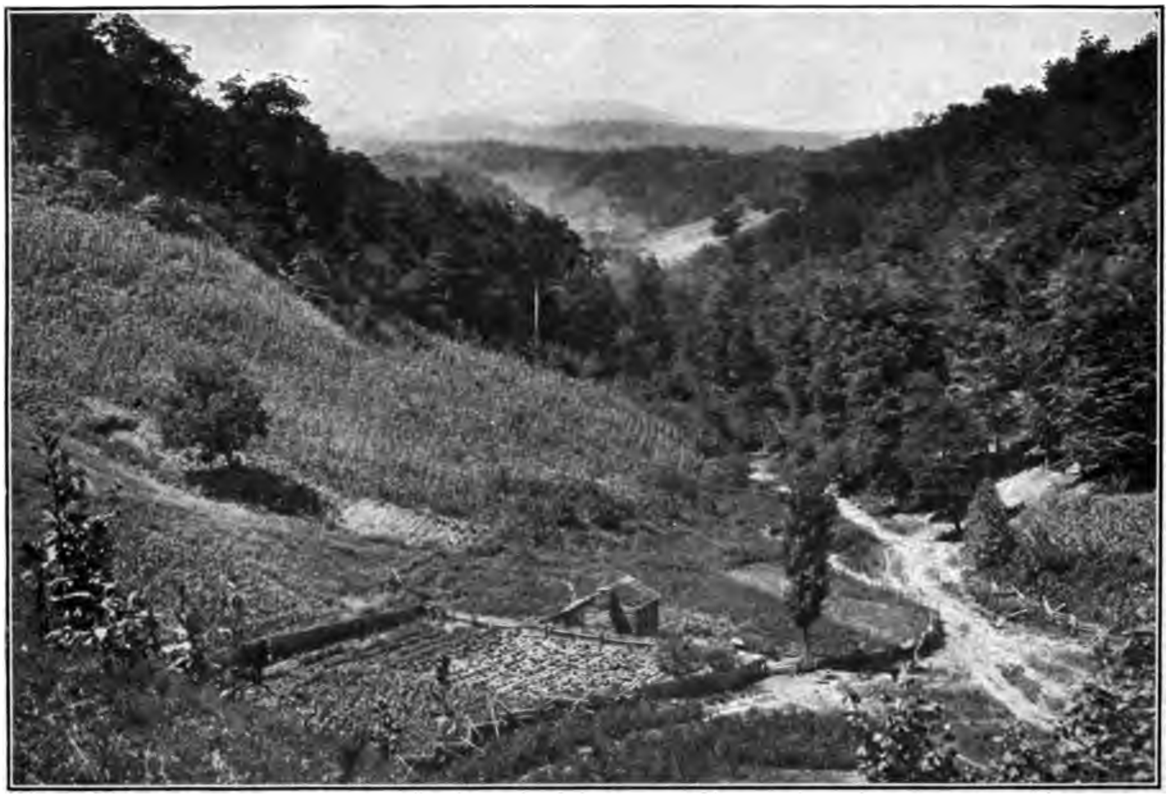
West of Middlesboro, with exception of the broad plain about the city, the streams have little or no bottom land. They fall rapidly in their lower courses, and in their upper courses often have not a much steeper gradient than in the lower ones. This is shown in the accompanying profile and cross sections (figs. 3 to 5). For the sake of the comparison the two profiles from the two districts have been placed together. The valley type found east of Middlesboro tends to render the lower coals accessible over a longer line and makes approach by rail easy, but cuts out no small area of those coals. The type found west of Middlesboro tends to preserve larger bodies of the lower coals, but leaves a larger portion of them below the immediate drainage and renders approach to any of the coals by railroad difficult on account of the high grades and narrow valley bottoms.

The amount of the fall of Cumberland River from Harlan to Pineville makes it evident that Pine Mountain is not the only check to the downcutting of the



A. GRADATION OF CUMBERLAND RIVER.

Rocky Riffle, about 3 miles above the mouth of Hance Creek, where river flows over outcrop of hard sandstone. There may be a fall of several feet in a quarter of a mile at such a place, and above will usually come a graded stretch with a broad valley.



B. PHYSIOGRAPHY OF UPPER WALLINS CREEK VALLEY.

View down Wallins Creek from just above the mouth of Long Branch, which shows the beginning of the bottom lands and about the highest point to which a road or a switch can be built without heavy grades.

river. Thus from the mouth of Yellow Creek down to Pine Mountain the gradient is less than 3 feet to the mile; between Yellow and Puckett creeks it is from 5 to 7 feet to the mile; for several miles from a little below Puckett Creek it is again about 3 feet to the mile; from near Saylor Creek to Harlan it varies from 4 to 10 feet to the mile. Between Harlan and Cawood the fall of Martins Fork runs from 4 to 15 feet per mile; between Cawood and Smith post-office, on the other hand, it is reduced to from 4 to 5 feet to the mile, being only 40 feet in 9 miles. Between Smith post-office and the mouth of Bull Branch the descent ranges from 20 to over 60 feet to the mile. Above Bull Branch the grade increases, seldom being less than 80 feet to the mile, and toward the head becoming over 200 feet to the mile. Pl. III, *A*, shows one type of river gradation—a succession of rocky riffles. As a whole the river can not be said to be graded; that is, to have acquired such a slope that its transporting and eroding powers are equal. In its long reaches, however, it has come to grade, as is evidenced by such broad bottoms or flood plains as are shown by the map. At no place was the

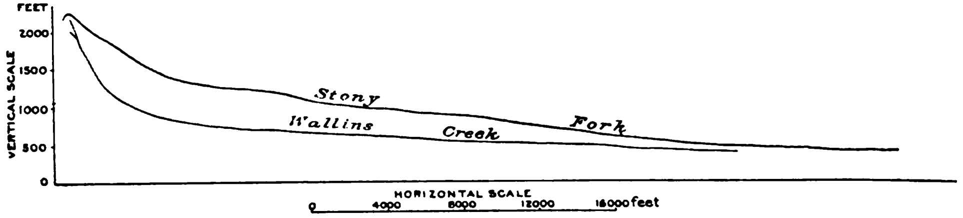


FIG. 3.—Profiles of Wallins Creek and Stony Fork of Yellow Creek.

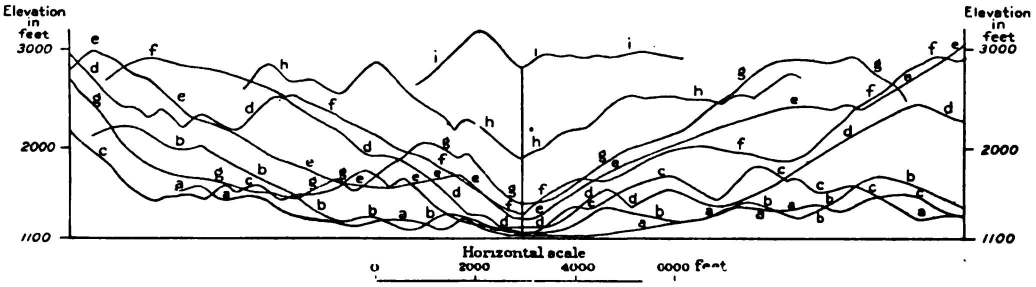


FIG. 4.—Stereogram of Wallins Creek Valley.

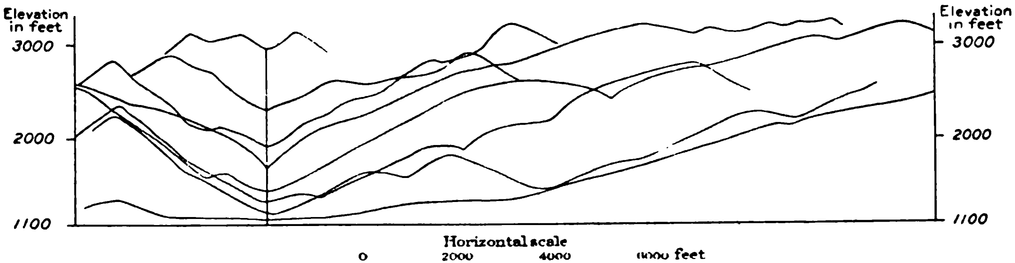
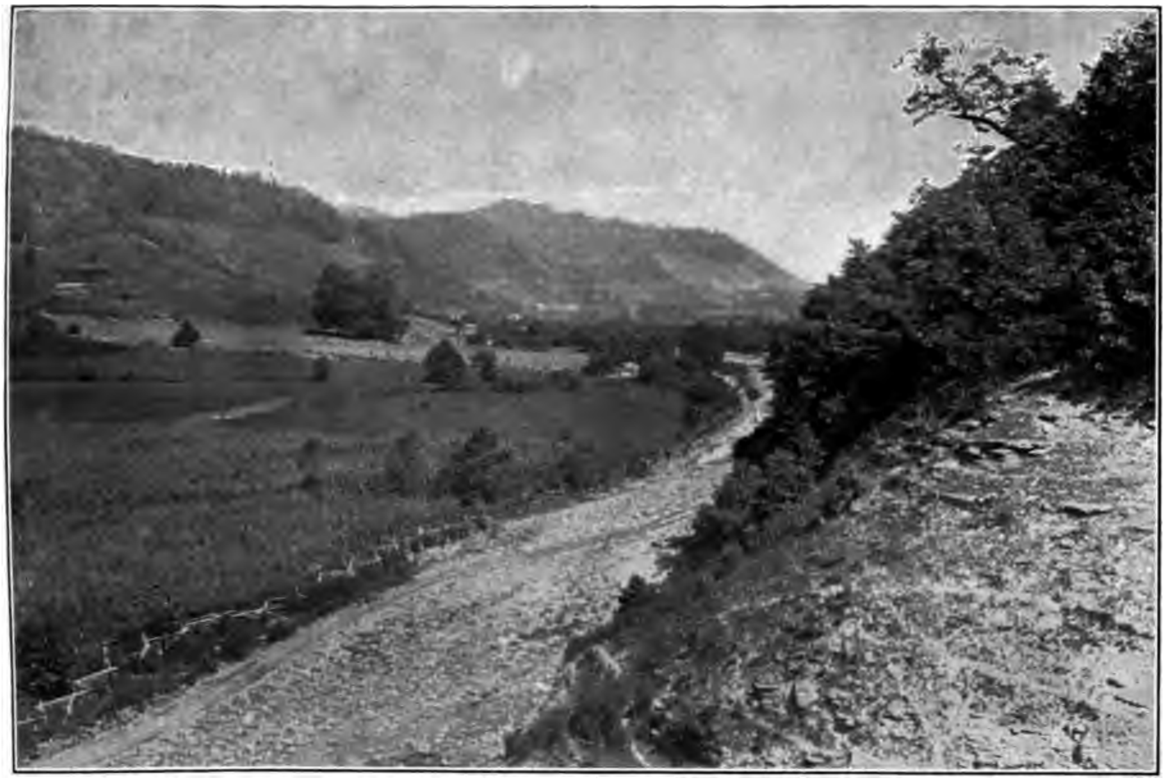


FIG. 5.—Stereogram of Stony Fork Valley.

river observed flowing over a ledge of rock. Pl. III, *A*, gives a near view of a riffle at low water composed, as shown, of large to small masses of rock. In some cases such riffles are evidently produced by the fall of rock from cliffs along the bank; at other points as here they would seem to result from the outcropping of a hard sandstone under the river bed. In some cases the existence of such riffles has been taken as evidence of the presence of an unseen rock sill at or just above that point. In places the valley is broad and open, as near Saylor Spur; in other places there is little or no flat bottom land (Pl. III, *A*), the latter places usually coinciding with points where one of the massive sandstones outcrops just at drainage level.

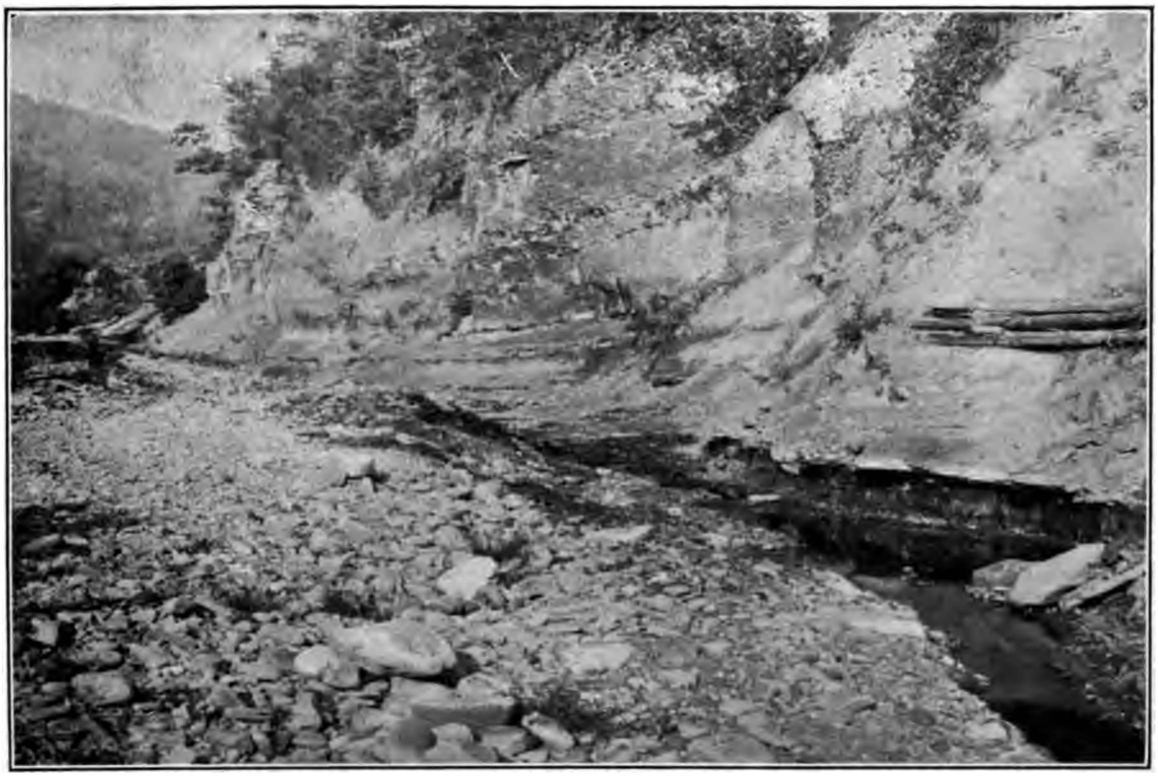
Wallins Creek and its tributaries are typical of the side valleys of the Black Mountains (Pls. III, *B*, and IV, *A*). The main creek as well as its tributaries head in amphitheater-like valleys, which are shaped like an inverted half cone with an angle of slope of about 45°. Starting from the narrow crest, the valleys descend often 500 feet in the same horizontal distance, sometimes less. The little streams cut but a few feet into the slope. In the second 500 feet the streams fall almost as steeply as before, but the general slope, as determined by the interstream divides, becomes much less steep, until by the joining of the many branches of the head the dividing ridges are cut off rather sharply. In the next 500 feet fall the slope becomes much less steep, averaging about 1 foot vertical fall for every 4 feet horizontal advance. At the beginning of the next 500 feet fall the descent becomes as shown in the foreground in Pl. III, *B*. The grade is still high, but is low enough to allow the deposition of some of the coarsest material brought down from above and the formation of flood plains of limited extent. Lumber roads can easily be built up to this point, and railroad switches can reach up to this level on the main creek without switchbacks, though not up the side branches. Starting at an elevation 3,100 or 3,200 feet above tide on Wallins Creek, the fourth 500-foot stretch will reach the region shown on Pl. IV, *A*. In the last 500 feet the fall decreases from over 200 to about 30 feet to the mile. The stream builds broad flood plains composed in the main of coarse gravel with a filling and cover of fine sediments. The lower courses of such a creek are graded, notwithstanding the steepness of the slope, for the side branches enter them with high grade (1 to 3 or 1 to 2 at the lowest), and thus keep them well supplied with coarse material, so that erosion is mainly lateral and much of the work of the stream is expended in distributing the material carried into it by the steep side branches. These side valleys, as already indicated, usually have no flood-plain deposits or level bottom lands, but are sharply V-shaped. In the case of Wallins, Puckett, Forrester, and smaller streams flowing into Cumberland River, the breadth and low grade of the main valley are probably due to the fact that for long distances the streams are cut out of the Hance shale, the structure being such as to allow the stream to follow the dip.

In the region west of Middlesboro the streams run transverse to the dip or along the strike in a general way. They therefore erode in a shale bed but a short distance before they cut down to an underlying sandstone the structure keeps the thicker shales at such a low elevation that in the case of Bennett Fork and Stony Fork the shales are only reached a short distance above the junction



A. PHYSIOGRAPHY OF LOWER WALLINS CREEK VALLEY.

The valley here is wide and fertile. The Cumberland Valley, with Pine Mountain rising behind, shows in the distance. In the lower right-hand corner is seen the outcrop (here thin) of the Cawood sandstone.



B. CHARACTERISTIC BLUFF OUTCROP OF HANCE SHALE.

Crummies Creek opposite the mouth of Little Creek. Fuckett Creek coal exposed at the foot of the bluff. Almost all of the lower courses of the streams are cut in these shales.

of the two forks. The result has been to produce valleys with fairly uniform grade from head to mouth. Thus, Bennett Fork descends 500 feet from the gap at the head in a distance of 1 mile instead of one-tenth of a mile, as in the case of Wallins Creek, while a short distance above the mouth Bennett Fork has a fall of from 100 to 120 feet to the mile, as contrasted with 30 feet to the mile in the case of Wallins Creek. As might be expected, the amount of bottom land on those forks is very limited, and the valleys are still sharply V-shaped. This shape of valley means that proportionately less of the coal has been removed than in the case of the hills cut by valleys of the type of Wallins Creek, but on the other hand the low grade of the latter streams allows ready access to the coal by railroad branches. A comparison of the two types can best be seen in a graphic representation of their profiles as is given in fig. 3, p. 21.

THE MIDDLESBORO PLAIN.

The topography of the basin around Middlesboro is unlike that in any other part. The salient features of the surface there are an open basin, a broad, nearly level plain, and a series of low hills.

The basin is approximately circular, being about 4 miles long from east to west and about 3½ miles wide from north to south, and on the 1,300-foot contour has an area of about 10 or 12 square miles. Perhaps the next nearest approach to such a basin in this region is the open valley at "Skidmore's bottom" on Martins Fork above Harlan. This, however, has an area of probably less than one-half square mile, or less than one-twentieth of the area of the Middlesboro basin. This basin at Middlesboro is surrounded on every side by mountains that rise from 1,000 to 2,000 feet above its level. About one-half the basin is occupied by a broad, irregular, nearly level plain. Across this plain Yellow and Little Yellow creeks meander sluggishly, though through the town of Middlesboro Yellow Creek is confined to a straight, planked, artificial, lined channel.

Low hills surround or rise from this plain, and an examination of the map shows that there is here a basin within a basin. These hills appear to be remnants of a higher base-level. They are sublevel on top, rise abruptly from the plain, and in most cases are nearly or quite surrounded by it. The Belt Railroad on the south and the road which follows the old Belt Railroad grade on the north barely rise above an elevation of 1,160 feet, but inclose a majority of the hills mentioned, although their summits nearly all rise above 1,200 feet and in one case over 1,300 feet. In the area within the line or grade of the Belt Railroad about forty points reach an elevation of 1,200 feet, while about twelve points have an altitude of 1,220 feet and only two points reach an elevation of 1,240 feet. The constancy with which these hills rise to about 1,200 feet above tide suggests very strongly that a local and temporary base-level existed at about that altitude. This may be called the Arthur Heights peneplain, from the name given to the summits of these hills just north of the business part of Middlesboro. Outside of the line of the Belt Railroad other points rise to 1,200 feet, but toward the north the tendency is for the hills to rise to from 1,220 to 1,260 feet. In general the hills north of the latitude of Middlesboro are a little higher than those south of that line. The hills on the south barely reach the 1,200-foot valley floor. That the difference between the former lower erosion level and the present drainage level is considerable is strongly suggested by the topographic features just described. While the town gets its water supply from Fern Lake, several wells have been sunk for the supply of commercial establishments. No accurate records or data could be obtained at any of these, but reports on good authority are that in at least one case a well 175 feet deep did not reach the bottom of the silt deposit.

It is said that water is found all over the flat land at a depth of about 4 feet, many of the wells being from 14 to 18 feet in depth. Mr. David G. Colson was able to force a pipe with a well point on it down 33 feet, where sand was struck, yielding an abundance of fine, cold water. Mr. W. H. Gildersleeve furnishes the following data in regard to the well at the tannery:

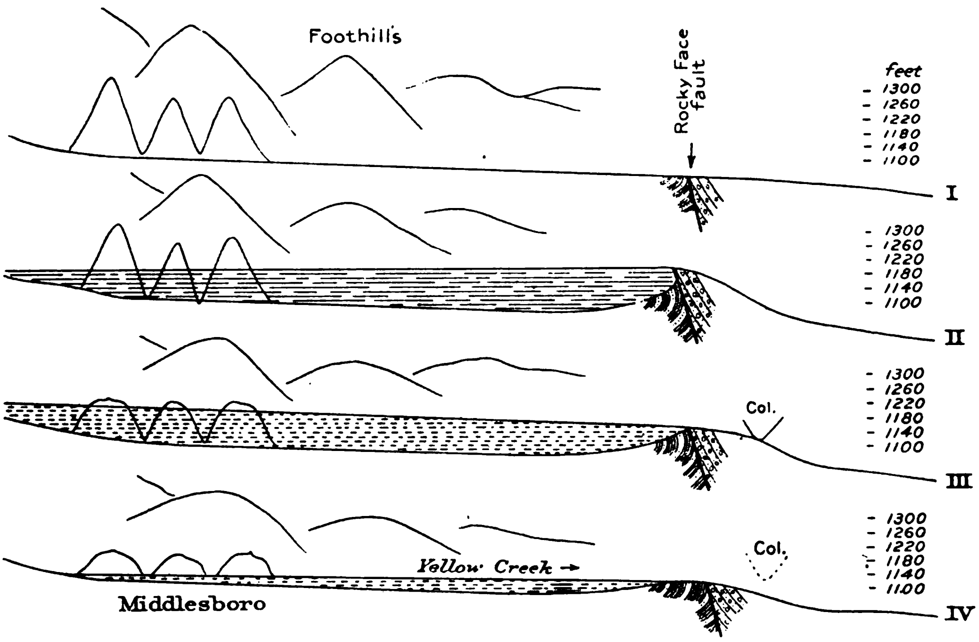


FIG. 7.—Sections showing theoretical and idealized stages in the formation of Middlesboro Plain.

"As near as I can find the well was put down 940 feet. Through the first 400 to 600 feet great difficulty was experienced by the sides caving in. This, I believe, was caused by striking beds of quicksand between layers of clay and soft shale or slate. After passing 500 to 600 feet sandstone was struck, varying in hardness, and at times pure white. I am told also that two or three beds of coal were struck, but I could not learn at what depth. I believe that drilling was stopped in a porous sandstone at the above-mentioned depth."

It is now impossible to say how much of the caving through the first 400 to 600 feet was due to the presence of alluvial unconsolidated rock and how much to the presence of shales, which being crushed and broken and folded to high angles would be apt to cave.

On the whole it seems safe to assume that there has been filling here to a depth of at least 30 or 40 feet; and, judging from the topography and of reports of first wells drilled, of possibly 150 feet or more.

Five questions are raised in attempting to account for the topographic features around Middlesboro:

(1) What conditions allowed the cutting out of the broad basin?

(2) Did the cutting of the upper gradation plain precede or follow the cutting of the lowest drainage lines?

(3) What barrier prevented the downcutting of the basin below the upper gradation plain at that stage in the history of the basin?

(4) What conditions caused the erosion of the valley below the present level?

(5) What later change determined the level of outflow so that the waters were ponded and the basin filled to its present level?

In regard to the conditions that allowed the cutting out of the broad basins, the rocks in this basin are predominatingly shales, which are folded, faulted, and crushed, and which, it is believed, are weak enough to allow the erosion of part or all of a basin such as this. Local subsidence, as described beyond, may have been in part responsible.

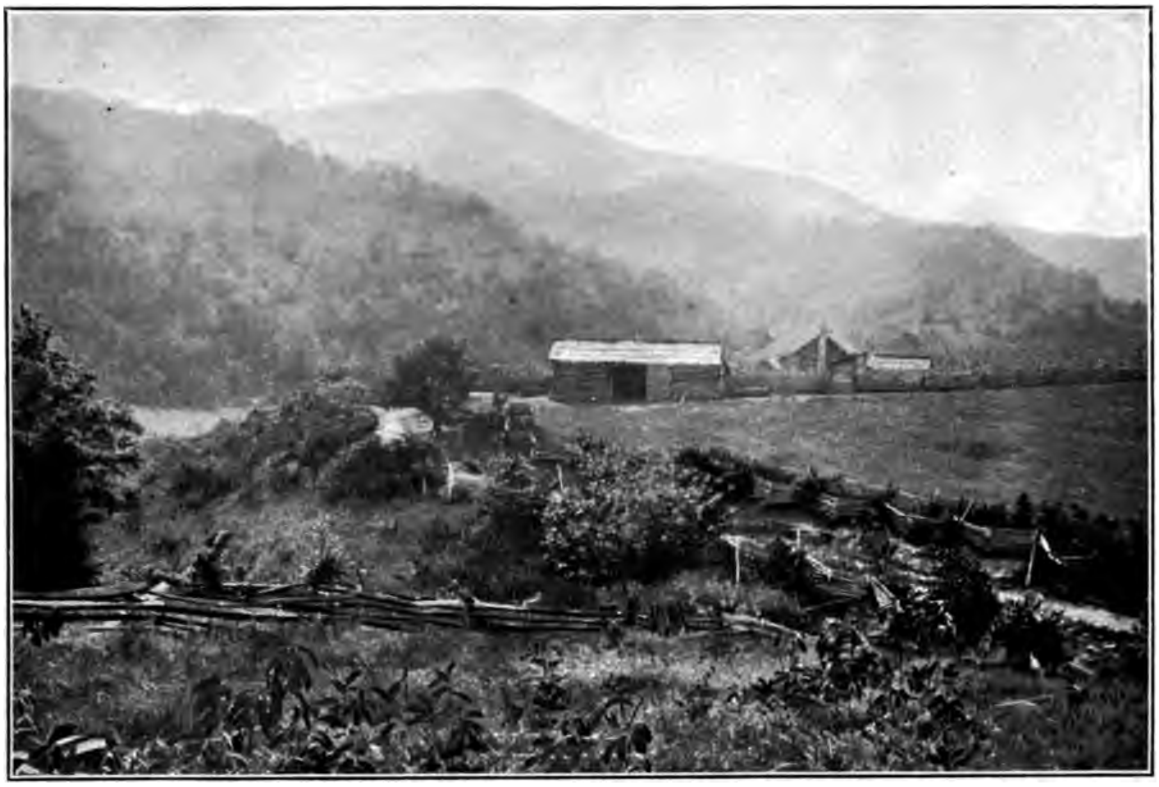
With respect to the relative ages of the upper gradation plain and the lowest drainage lines, the series of events may have been in accordance with one of two hypotheses. According to the first hypothesis, the sequence would have been as follows: (*a*) Erosion to lowest level; (*b*) elevation of outlet, Arthur Heights plain; (*c*) lowering of outlet to present level. According to the second hypothesis, the development would have been thus: (*a*) Erosion down to upper gradation or Arthur Heights plain; (*b*) lowering of outlet to allow lowest erosion; (*c*) elevation of outlet to present position. It would seem highly probable that if the deepest erosion level had been cut before the upper gradation plain was formed, benches of silt or gravel in sheltered positions should be found flanking the slopes between the present and higher plain levels. No such benches were seen, though it can not be asserted that they do not exist. Traces of gravel were found at a few points a little above the level of the present or lower plain. Considering the completeness of degradation to the level of the upper plain the lack of benches seems to indicate that the erosion to the upper plain preceded the downcutting to the lowest erosion level. However, the answer to the third question so closely connects the upper and present gradation plains as to incline the writer to the belief that the upper plain was formed after the cutting of the rock floor under the present plain.

If the Arthur Heights plain stage were only a pause in the original downcutting of the valley, the barrier that prevented the downcutting of the basin below the upper gradation plain may have consisted of a hard layer of rock, which either was finally eroded through or prevented erosion below it until a tributary of some other stream tapped this drainage and rapidly degraded the surface to a lower level. If the order of events given was in accordance with the first hypothesis, the same explanation may be given for the reduction of the local drainage level from the Arthur Heights plain to the lower present plain. In that case it is possible that Yellow Creek may have originally flowed through the low gap just east of

Moore Knob, now tunneled by the railroad. This gap has at present an elevation of about 1,170 feet. A fork of Williams Creek may have tapped it at the present mouth of Cannon Creek. The Yellow Creek road between the mouth of Clear Fork and Turnhole Branch leaves the lower valley and crosses an old col, containing alluvial sediments. A mile above its mouth Clear Fork is separated from Yellow Creek by a low, narrow divide that will be cut through in a comparatively short time. As the channel of Clear Fork is at least 20 feet lower than that of Yellow Creek, on the opposite side of the divide and but a few rods away, it is evident that when Yellow Creek cuts through the divide there will be formed a waterfall or rapid that will more or less rapidly move up the creek toward Middlesboro. Though this undercutting of the old level will constantly decrease, its influence would certainly extend to Middlesboro, and the present plain there would be partly destroyed and a new one begun at a slightly lower level.

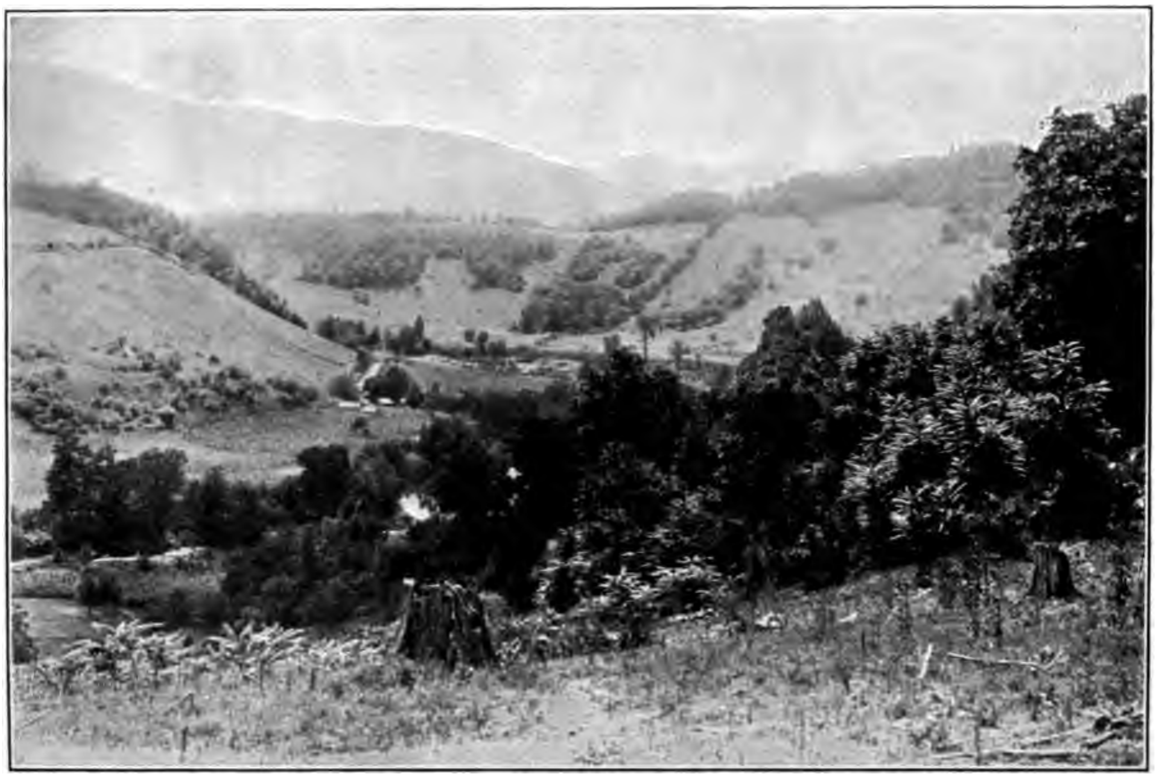
Another result of the cutting through of the narrow divide would be that the present channel of Yellow Creek between the narrow divide and the mouth of Clear Fork would be left as a col more or less similar to that now traversed by the road between the mouth of Clear Fork and Turnhole Branch. In view of this comparison it seems highly probable that Yellow Creek at a comparatively recent date ran through the old col mentioned. At the same time Clear Fork and Cranes Creek were cutting a channel a little to the east of this and at a somewhat lower level, due to the fact that they were cutting in shale while the floor of the channel where the col is now is hard sandstone. As a result of the eastward dip of the rocks on the upthrown side of the Rocky Face fault the channel of Yellow Creek had a tendency to erode down the slope toward the east until it cut through the divide and emptied into the valley of Clear Fork. The result of this was the destruction of the Arthur Heights plain then existing at Middlesboro, and the starting of what finally became the present plain. The present channel of Yellow Creek near the col is about 70 feet below the floor of the col, and there is almost the same difference between the upper planation level at Middlesboro and the present plain. This seems to account for the two planation levels at Middlesboro so satisfactorily, and to connect those levels together so closely, that the writer is led to accept the first hypothesis given above and to conclude that the low-level erosion preceded the formation of the upper level and that the upper and present levels represent two stages in the general reduction of this basin after the period of uplift of the outlet level.

It still remains to determine the conditions that caused the low-level erosion and those that afterwards stopped that erosion, ponded the waters, and allowed the basin to be filled with silt to the present 1,200-foot level or above. The grade of the present channel of Yellow Creek below Middlesboro changes decidedly at the south end of Rocky Face Mountain, being eight times as steep below as above that point. Above that point the grade is only a trifle over 2 feet to the mile, and the stream is sluggish and meanders where the valley is wide enough. That it has not widened its valley more between Excelsior and Rocky Face Mountain is evidence of the youth of that part of the valley. It would seem evident that at present and probably for some time in the past the level of the upper valley of Yellow Creek has been determined by the hard sandstones upturned



A. BENCH OF CAWOOD SANDSTONE ON MARTINS FORK.

A road runs on top of the outcrop of the sandstone forming the bench upon which the farm buildings stand.



B. BENCH RESULTING FROM DIFFERENTIAL WEATHERING OF SHALE AND SANDSTONE.

View of Cawood sandstone bench, looking south across Poor Fork and Martins Fork, from near the junction.

in Rocky Face Mountain. While rock was not seen in place in the bed of Yellow Creek at the south end of Rocky Face Mountain, there is strong evidence that it is present there below the loose rock forming the riffles. The valley at that point is very narrow, not over 200 feet wide 40 feet above the low-water level. On the south bank a perpendicular cliff of sandstone rises from the water and on the north bank there is barely room for a wagon road between the creek and a steep bank with massive outcrops of sandstone. The present fall of Yellow Creek to this point from Middlesboro, 8.8 miles along the course of the stream, is 20 feet. Evidently if the erosion level at Middlesboro is lower than at this point either the rock at this point was lower than at present or the general elevation of the Middlesboro district was higher. If, as reported, wells at Middlesboro have gone 175 feet into the silt deposit without reaching the bottom, the altitude of the old erosion level must have been less than 965 feet above tide, or below the present level of the Pineville gap. Again the valley of Yellow Creek at and below Excelsior Mine is so very narrow that it hardly seems possible for it to have been eroded much below its present level and silted up. If the filling at Middlesboro were only 30 or 40 feet, it might be as great in this valley, narrow as it is, but hardly greater. In that case the facts could be explained by assuming that along the Rocky Face Mountain fault the upthrown rocks on the east had received a recent and possibly final upthrust. Taking only the facts as they can be seen on the surface this seems to be the best explanation of the origin of the barrier that ponded the waters.

If the reported depth of the deposit about Middlesboro be accepted the problem becomes more difficult, for a differential movement of about 250 feet (to the upper planation plain) must be accounted for. It is evident that the lower erosion level can not be accounted for by supposing that the hard layers forming the rock sill at the Rocky Face Mountain fault were much lower, for were they entirely below the reach of the drainage lines the rock sill at Pine Mountain would have prevented the lowering of the valley at Middlesboro below 1,060–1,100 feet, or at least 100 feet less than is required. Nor does it seem possible to assume that Pine Mountain at that time stood that much lower than at present, for without denying possible movements along the Pine Mountain fault, the Cumberland Valley above Pine Mountain does not indicate movement of any such amount. And further, the narrowness of the valley near the Excelsior mine is decidedly against the valley at that point ever having been 150 feet below its present level. It therefore seems necessary to assume that at the time Yellow Creek was cutting out its deepest channel the rock beds about Middlesboro were from 125 to 250 feet higher than at present. The higher figure may be accepted if it is assumed that the only subsequent movement was a sinking immediately around Middlesboro; the lower figure may be taken if it is assumed there has been uplift at Rocky Face Mountain while sinking was going on at Middlesboro. In either case it is almost certain that there have been earth movements of some magnitude in this region, probably as late as the Pleistocene or late Tertiary. (See pp. 46–50.)

mined, either by a line of large partly weathered bowlders along its outcrop, or more frequently by large masses of rock on the slope below its level of outcrop. The slopes below the more prominent cliffs are usually strewn with large bowlders, slowly working their way down the hill.

Another type of cliff is formed at the lower edge of the slopes, where the side swinging of the streams erodes the underlying shales, as shown on Pl. IV, *B*.

These slope features have been described in some detail and quite fully illustrated, as in a region like this, where measurable outcrops of the coals are few and scattered, the coals can be traced or the rocks of different districts correlated only by using all the features which will be of assistance in tracing the outcrops of prominent beds (usually sandstones) lying near the stratum being mapped.

The long columnar sections given in the discussion of the coal were obtained along the creek beds and the long, sharp noses. Along the stream beds the rocks are either cleanly exposed or entirely covered. Near the heads of the ravines in the Black Mountains, where the streams frequently have a slope of more than 45°, the rocks are sometimes exposed cleanly and almost continuously for hundreds of feet vertically. In such sections, as a rule, coals may be measured to the fraction of an inch. In the Black Mountains the bulk of the measurements of coals, except those on the Harlan coal, were obtained in the stream beds. Along the lower courses of the streams the coals are sometimes exposed in the faces of the shale bluffs (Pl. IV, *B*). Most of the measurements of the Harlan, the Kellioka, and the Puckett Creek coals were made at little country banks at which detailed sections of the coal are readily obtained and at which it is usually possible to see the character of the roof and under clay (Pl. XVII, *B*).

DRAINAGE.

The drainage of the portion of the Cumberland Gap coal field studied is entirely by the Cumberland River. The possible origin of that drainage has already been described. The drainage as it exists to-day is sufficiently well shown by the map and needs no further description. It only remains to call attention to the influence of the structure on the drainage. In a general way the Cumberland River from Harlan to the mouth of Yellow Creek is flowing along the axis of the syncline or in the lowest part of the structural basin. Actually it is a little northwest of that line. The succession of long tributaries from the southeast, Williams, Hance, Puckett, Wallins, etc., are flowing down the slope of the rocks; in some cases the dip of the rocks and the grade of the streams being practically equal. Poor Fork and Clover Fork, in their lower courses at least, flow in the Hance shales as those shales rise in either limb of the Big Black Mountain syncline. Clear Creek, Poor Fork, Cranks Creek, Martins Fork from Cranks Creek to "The Narrows," Brownies Creek and Cubage Creek, Clear Fork of Yellow Creek, and Little Yellow Creek all flow in the shales immediately overlying the basal sandstone. Their courses are determined, in the main, by that shale which occupies a narrow linear belt whose position is determined by the uplift of the Pine or Cumberland mountains.

CULTURE.

Until within comparatively recent years this region has been entirely without railroad facilities, so that agriculture and lumbering have been the only industries.

Now the Southern Railway and the Louisville and Nashville Railroad enter this field. In a very few years the mining of coal commercially has sprung from nothing to nearly or quite a million tons a year. The reduction of iron ores is now carried on extensively at Middlesboro, and other enterprises are in successful operation. The flat valley lands are practically all under cultivation, and considering the steepness of the mountain slopes a surprisingly large area of such slopes is under cultivation. Bridges are almost entirely lacking, and most of the roads are but little suited to hauling produce or merchandise; almost everything at present is transported in bags slung across the backs of horses or mules.

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The outcropping rocks of the Cumberland Gap coal basin consist of shales, sandstones, clays, and coal beds. The only limestones found are a few layers of calcareous shales or sandstones in which a bed of contiguous concretionary blocks is developed. No continuous limestone layer was seen, though a layer of black limestone is reported to occur high in the Black Mountains; a single float fragment of such a limestone was found. The shales and sandstones are about equally developed, though possibly sandstone predominates. Sandstones predominate in the lower third or more of the section, and are abundant in beds of limited thickness (20 to 100 feet) all through the upper two-thirds of the sections. In fig. 8 are shown two generalized columnar sections which give an idea of the composition of the upper two-thirds of the section and serve as a basis for the division of it into formations. The lower part of the section is not only mainly sandstone, but contains some fairly coarse conglomerate; it

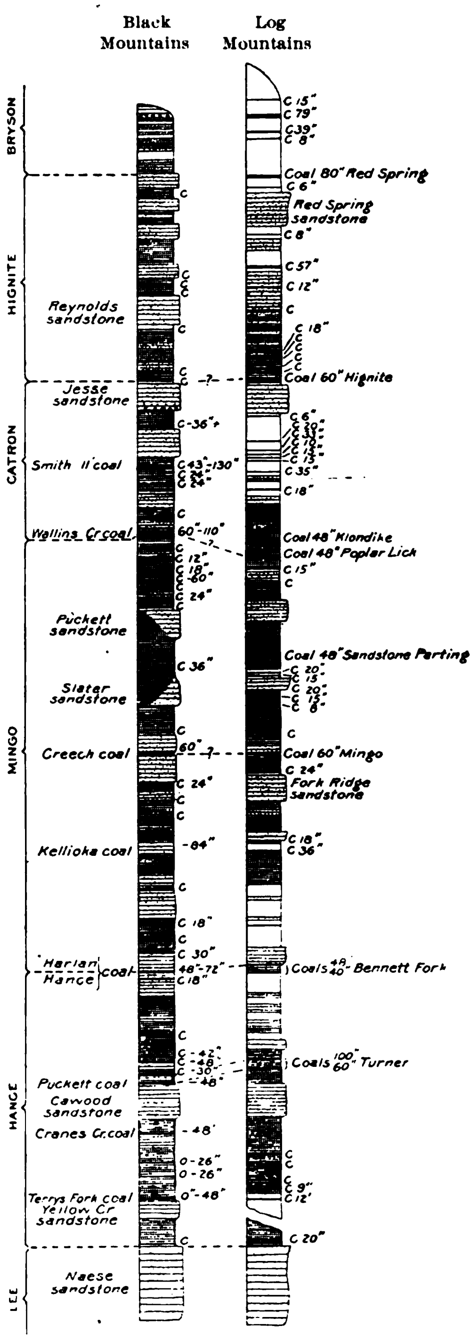

FIG. 8.—Generalized columnar sections of Black and Log mountains.

contains little coal, and in this region is usually below drainage or upturned at high angles in the enflanking mountains.

A study of the fossils found indicates that all of the rocks of this basin are of the age of the Pottsville group of Pennsylvania. All the coals at present worked in the Log Mountains appear to be certainly of Pottsville age. The formation in the lower part of the section appears to be the same as the Lee conglomerate of Campbell in adjacent regions to the north and northeast, and of Keith to the southwest. It is here called the Lee sandstone. The Lee is the lowest division of the Coal Measures, and none of the rocks below it outcrop within the Cumberland Gap coal basin unless they are exposed along the base of the fault scarp on the west side of Rocky Face Mountain. No such rocks were noted there, but they may occur above drainage level and lie hidden by the talus slope. These underlying formations are exposed on the north flank of Pine Mountain, where they are brought up by the Pine Mountain fault.

Above the Lee occur about 2,300 feet of sandstones and shales in about equal proportion and more or less uniformly distributed through the column. It is, therefore, not possible to subdivide this part of the section into formations whose lithologic characters are constant, and are different from those of the formations above and below. Nevertheless, for convenience of discussion and for purposes of mapping, it has seemed best to divide this part of the section into formations along arbitrary lines, the lines used being those that it was believed were traced over the whole area with some degree of certainty. In several cases these lines have been drawn at the horizons of valuable coals. In addition to the formation lines it has been possible in several cases to trace cliff-making sandstones over considerable areas, and as these are often valuable in helping to locate the coals, they are mapped and described as members.

In the table below are shown the relative position, thickness, and composition of the formations into which the rocks of this basin have been divided, as well as the position of the mapped coals and sandstone members.

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Formation.	Symbol.	Average thickness.	Members and coals.
		Feet.	
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Pennington shale.	Cpn	100	
Newman limestone.	Cn		
Chattanooga shale.	Dch		

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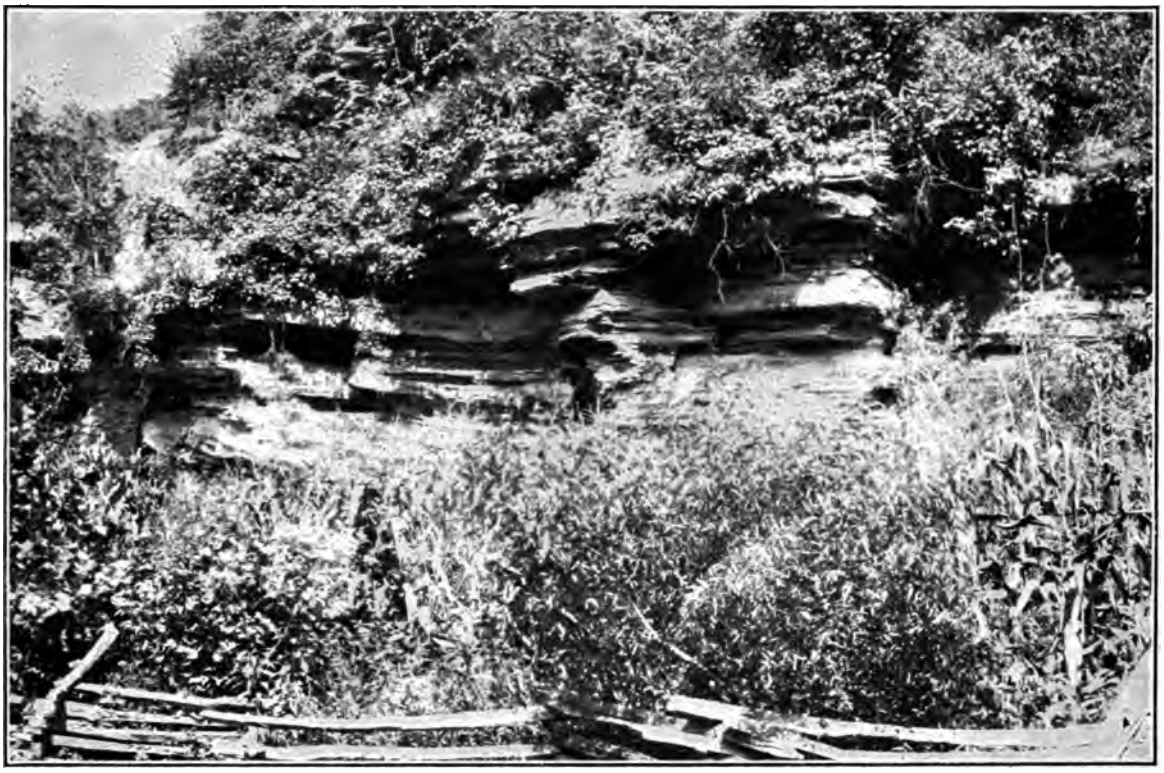
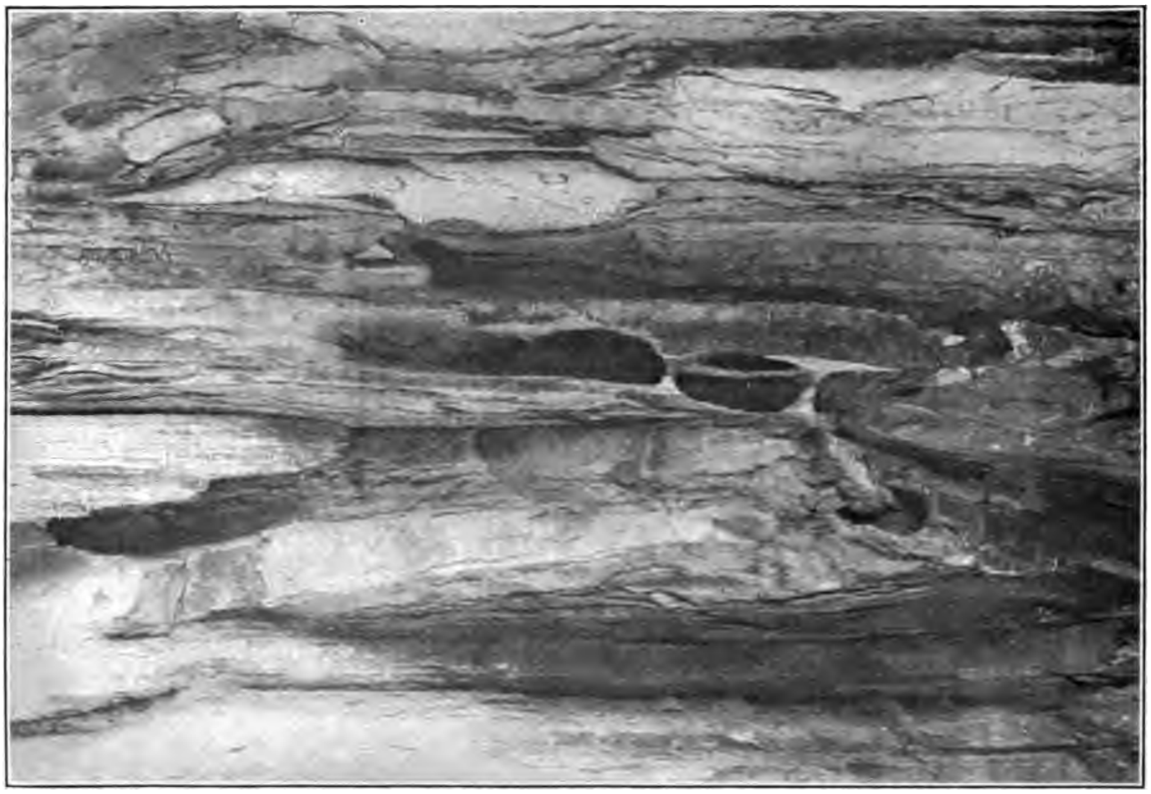
LEE FORMATION.

This is the massive sandstone that forms the base of the Pottsville throughout the southern Appalachian province. As the Lee formation of this region has not been traced to connect with the same formation as mapped by Mr. Campbell in the Estillville quadrangle to the northeast, or by Mr. Keith in the Maynardville quadrangle to the southwest, some uncertainty exists as to whether the upper and lower limits, as assigned here, agree with the limits given in the Estillville and Maynardville folios. Its upper limit has been taken as the top of the massive sandstone making up the Naese Cliff on the Cumberland River below the mouth of Brownies Creek. (See Pl. VIII, *A*.) Its lower limit has likewise been in doubt. It has been taken as the top of the first thick shale below the conglomerate. At Cumberland Gap this shale, which has been correlated with the Pennington shale of Campbell, has a thickness of 100 feet, and is underlain immediately by the white Newman limestones. As the Pennington shale has a thickness of 1,025 feet at Pennington Gap just east of the area here studied, there has been a remarkable thinning of the shale or else the lower sandstones between the conglomerate and shale belong in the Pennington shale. Even then the Pennington would be only 300 feet thick at



A. CAWOOD SANDSTONE JUST BELOW CAWOOD POST-OFFICE.



B. OUTCROP OF CAWOOD SANDSTONE AT TYPE LOCALITY.

Showing the weathering of the sandstone, leaving honeycombed effect from which the name Bee rock is derived.

from this 100 to 300 feet which belong to the Pennington, there is left from 1,200 to 1,400 feet as the thickness of the Lee formation. At Brierfield Gap a section was made on the road from Hurst to Hagan. This section when platted gave an estimated thickness of 3,700 feet between the top of the Lee and the top of the Newman limestone. In the road the dips were uniformly from 45° to 60°, so that at first sight it would seem as though this section could be relied upon to give the actual thickness. As, however, vertical dips and reverse dips were found only a little to one side of the line of the section, the possibility of faults occurring through the section reduces the probability of the section being correct. On the whole, therefore, it may be considered that this formation in this area has a thickness of at least 1,000 feet, and possibly of 1,500 feet. Its top is formed of the Naese sandstone member which makes the prominent Naese Cliff on Cumberland River about 8 miles by the road above Pineville. (See Pl. VIII *A*, p. 36.) This is the same sandstone that produces the well-known Seven Sisters, a short distance farther up the river. Near the Seven Sisters and on the lower part of Clear Creek it shows a thickness of considerably over 100 feet. As exposed along Cumberland River the upper part of this top sandstone is much cross-bedded, though sometimes it shows no true bedding planes in a distance of 50 feet or more. The bedding planes are variable in thickness within short distances, as though they were laid down in a region subject to varying currents. Parts of these layers show considerable areas where the sandstone is full of clay pellets; in places apparently similar pellets have weathered out, leaving the rock in a honeycombed condition, so that the term "Bee rock" has sometimes been applied locally to it. In places the rock shows a marked tendency to exfoliatation, leaving the surface below of a bright buff color and in rounded outlines. The two coals at Cumberland Gap appear to be the same coals that are found at other points in the Pine and Cumberland mountains, suggesting that they may be rather persistent. If so, these coals may some day be of value in the center of the basin where they are not disturbed by the folding or faulting. The main mass of conglomerate is usually white on a fresh surface, and sometimes on weathered surfaces, though usually it runs from gray to brown. It is a coarse-grained saccharoidal sandstone containing many pebbles of white to milky translucent colors. These are usually oval and well rounded and range from one thirty-second of an inch or less up to about 1 inch in diameter. The majority of the pebbles are small in most of the exposures, averaging nearer the one thirty-second-inch limit than the 1 inch. In most expo-

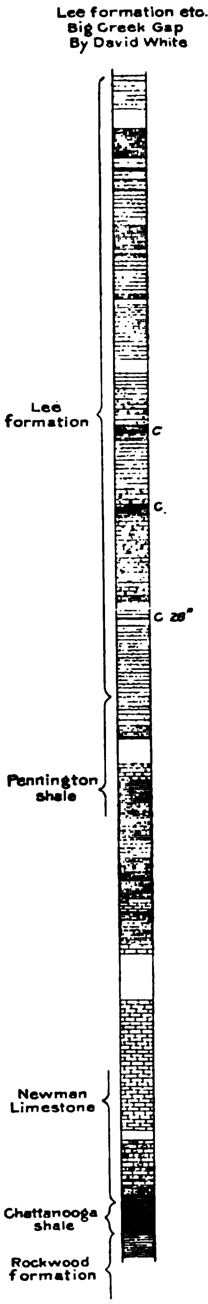
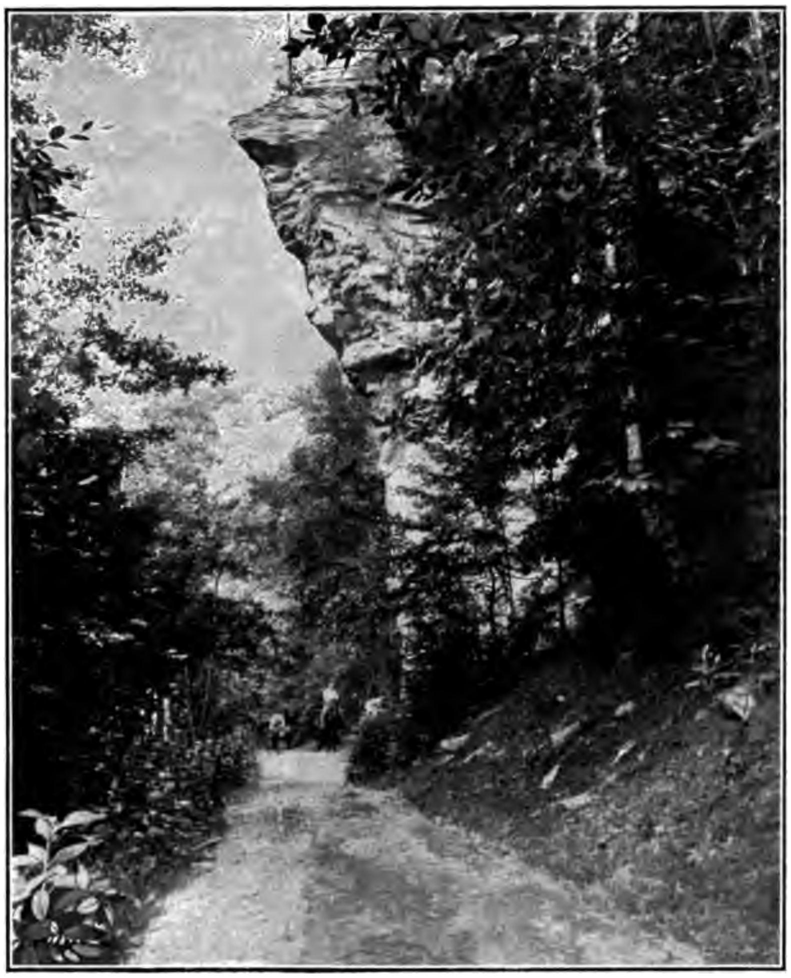
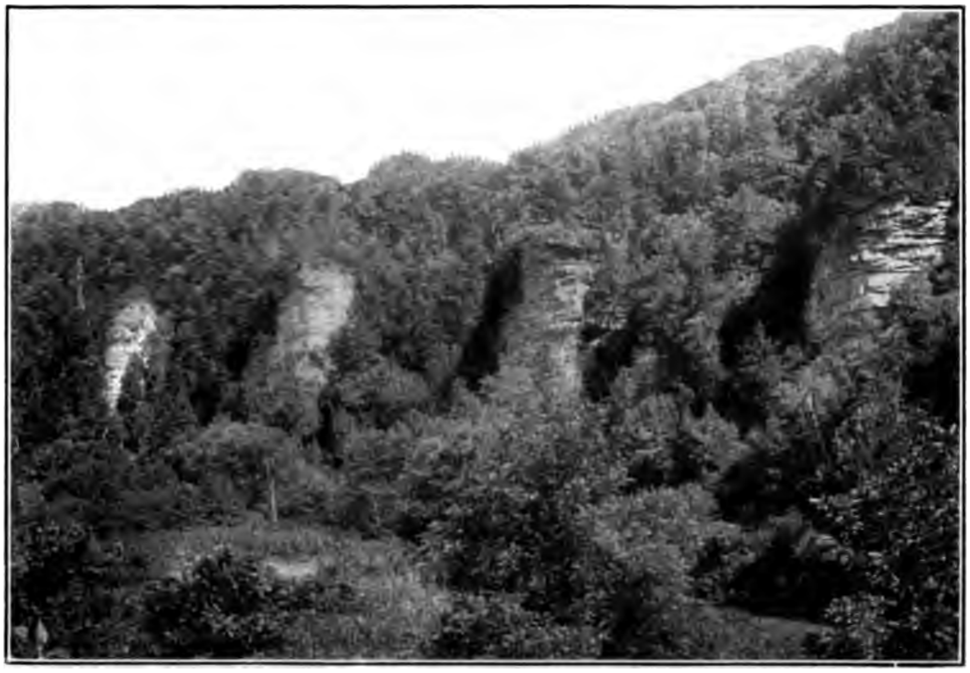


FIG. 9.—Columnar section of Lee and underlying formation at Big Creek Gap of Cumberland Mountain (David White).



A. OUTCROP OF NAESE SANDSTONE AT TYPE LOCALITY.

Naese Cliff, on Cumberland River, a short distance above the mouth of Hance Creek, from which Naese sandstone receives its name.



B. FOUR OF THE "SEVEN SISTERS."

A well-known locality on Cumberland River. These are outcrops of Naese sandstone, which in this field has been regarded as the top bed of the Lee formation.

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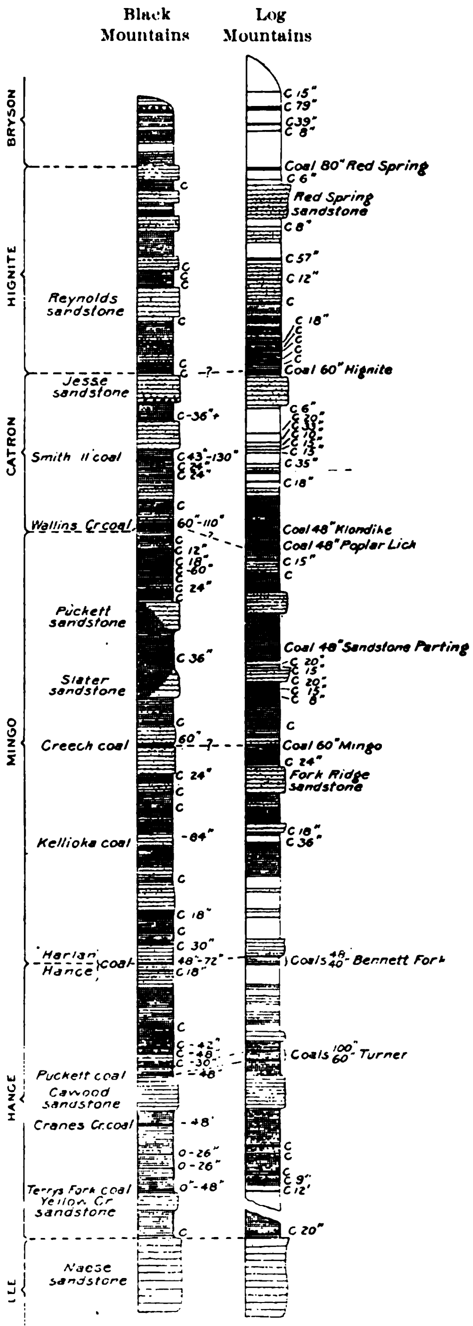

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Cumberland Gap and 500 feet thick at Cup Gap. At Brierfield Gap calculation gave 1,375 feet as the stratigraphic distance from the bottom of the conglomerate to the top of the Newman limestone. Doubt exists as to the continuity of the section there. On the almost perpendicular escarpment of Cumberland Mountain the following section is exposed below the Pinnacle:

Section at Pinnacle above Cumberland Gap.

	Feet.
Sandstone, coarse grained, and with scattered pebbles	50
Sandstone, coarse conglomerate	40
Sandstone, thin bedded to massive, hard, medium grained, light brown	20
Sandstone, hard, crinkly	60
Shale, brown	120
Limestone, "Newman" (estimated)	350
Shale, black, Chattanooga	150

It has been assumed that the conglomeratic sandstone at the top of Pinnacle belongs in the Coal Measures and is therefore a part of the Lee conglomerate. If that is so, the Pennington formation must be restricted to the strata between the limestone and the base of this conglomerate—a total interval of 300 feet. It will require further study to determine whether the 180 feet of sandstone below the conglomerate belongs in the Lee or in the Pennington. A good section of part of the Lee formation can be obtained by combining the exposures on the road from Middlesboro to Cumberland Gap with the record of a drilling made at the brewery at the foot of the hill. The total section is as follows:

Section of Lee formation on Cumberland Gap road.

	Feet.
Sandstone, shaly in places, more often massive, yellow (bottom of section)	90
Shale, sandy, brown to dark blue on road, "black" in well	50
Sandstone, shaly, gray, with thin interbedded layers of shale	100
Shale, fissile, brown to dark blue	10
Coal, up to	4
Shale, similar to last	15
Sandstone, massive	30
Shale, fissile, dark blue	25
Sandstone, ripple marked, pinkish and shaly near top, white, and more quarzitic toward bottom, generally massive	100
Coarse conglomerate, estimated by pacing	480
Coal, "Cumberland Gap," up to	6
Shale, brown and sandy	50
Sandstone, hard, fine grained in saddle of gap and somewhat resembling quartzite	80

From the saddle to the point where the limestone is exposed on the southwest side of the gap is a horizontal distance of 1,350 feet. As the rock in place is largely hidden it can not be asserted that it is sandstone or that the major part of it belongs in the Lee formation. As exposed on the road in the section just given, the Lee formation has a thickness of 1,000 feet. All attempts to tie the lower part of this section with the section on the opposite side of the fault were unsuccessful. At Cup Gap it was estimated that the Newman limestone was stratigraphically at least 1,500 feet below a hard, white sandstone that was thought to be in the Lee, and possibly to mark the top of the Lee. If there is subtracted

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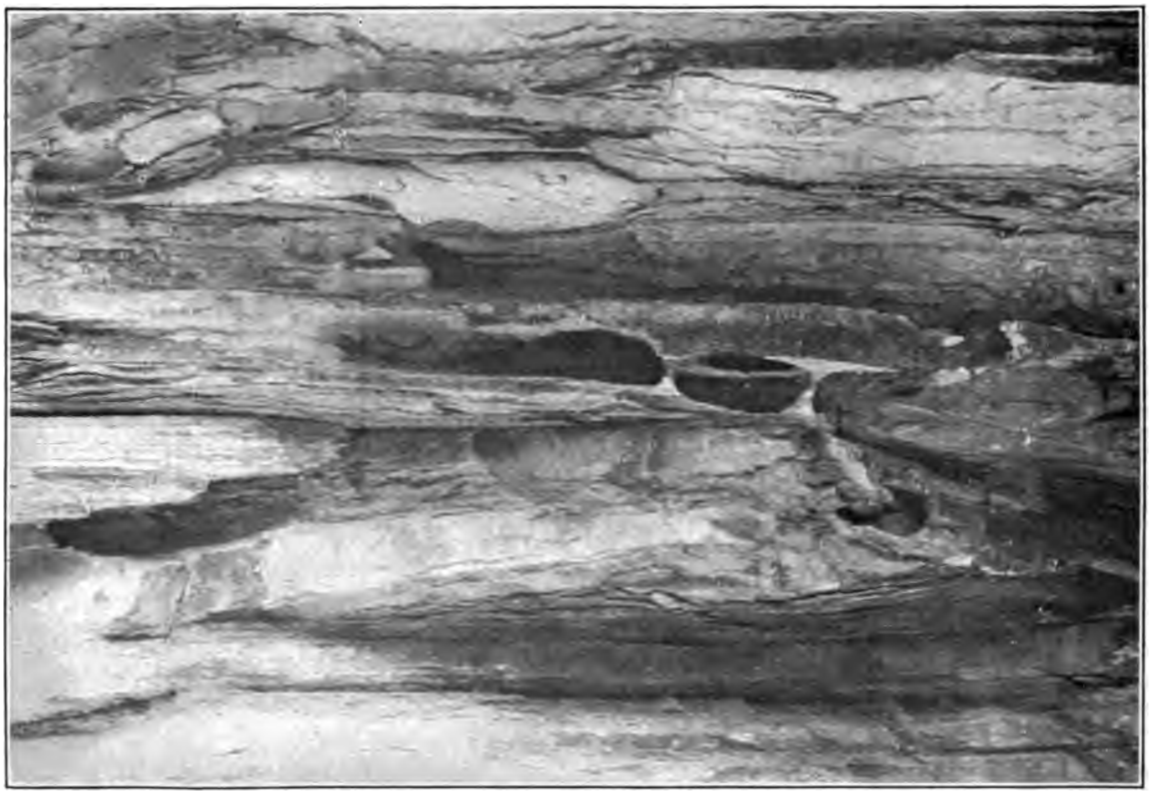

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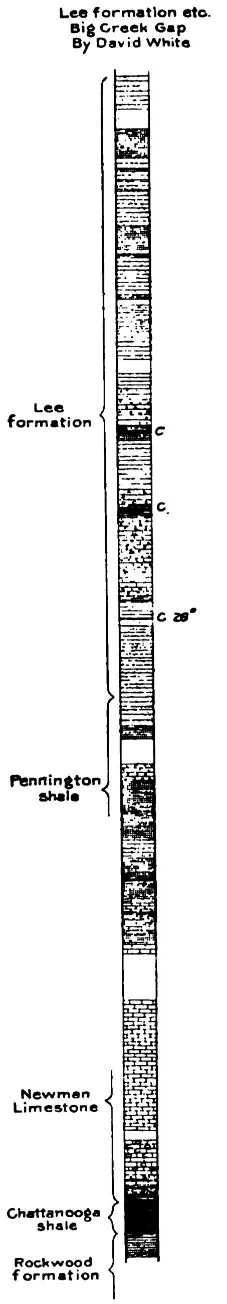


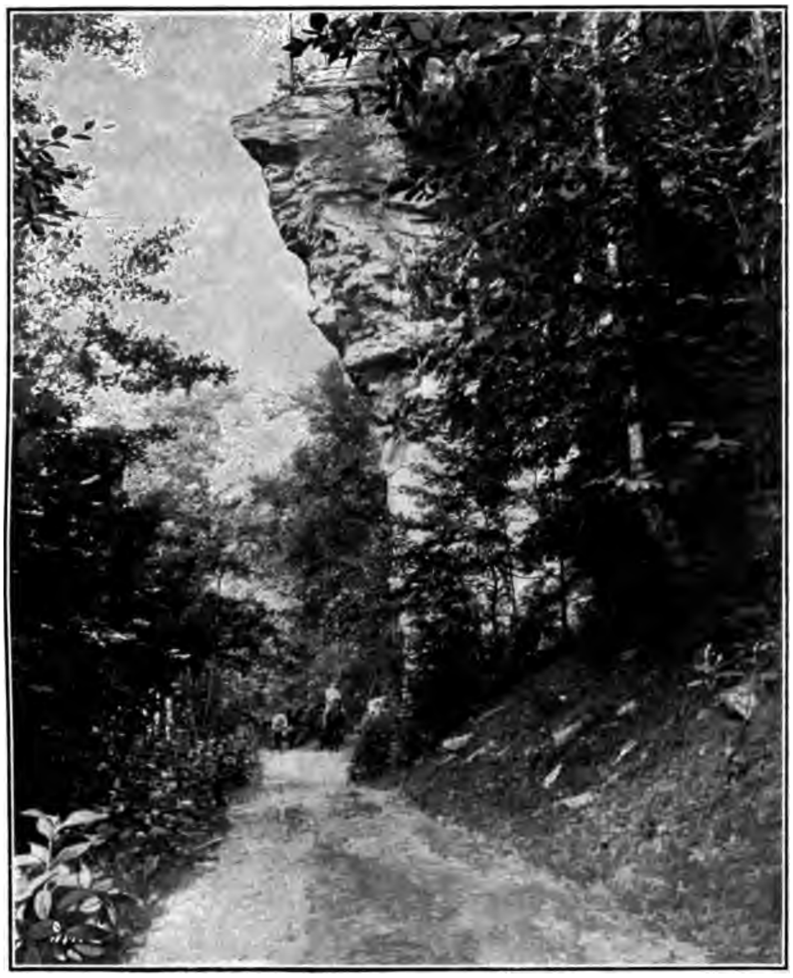
FIG. 9.—Columnar section of Lee and underlying formation at Big Creek Gap of Cumberland Mountain (David White).

sures the pebbles appear to be more abundant and larger near the bottom of the conglomerate. Near the top of the conglomerate the pebbles are scattered thinly, usually in lines along the bedding, and generally in a pockety manner. Here the pebbles over one thirty-second of an inch in diameter may not make up one one-hundredth part of the rock, while toward the bottom of the conglomerate in some layers probably nine-tenths of the pebbles are over one thirty-second of an inch. Some of the other sandstones of the Lee formation, while not conglomeratic, are coarse grained, white, and quartzitic, and from rock of this character it is possible that some building stone may be obtained.

At Big Creek Gap, just southwest of the area mapped, Cumberland Mountain is cut by Big Creek, and at this point Mr. David White obtained the following complete section of the Lee formation and the underlying formations:

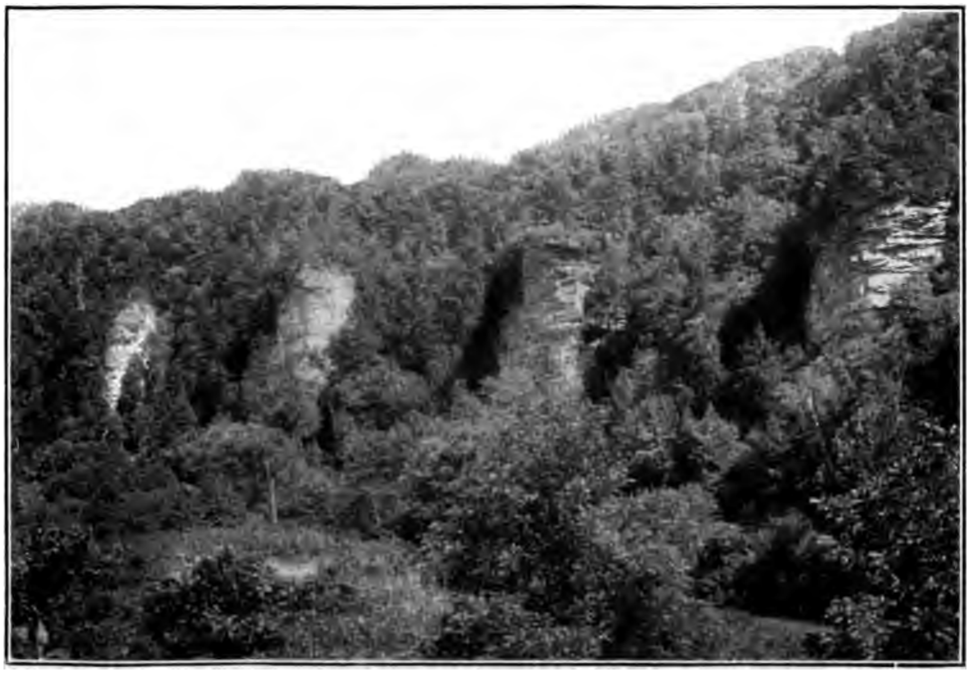
Section at Big Creek Gap (fig. 9).

	Feet.
Rex coal	
Interval	10
Sandstone, thin bedded, and shale	40
Interval, hidden	125
Sandstone, possibly "top of Lee formation," probably Yellow Creek sandstone of this report	70
Interval, hidden	40
Shale, dark and fissile at center	70
Sandstone, with some shale, probably with next representative of "Naese" sandstone	70
Sandstone	80
Shale, plant remains	50
Sandstone	10
Shales, dark, containing coal streak with invertebrates	5
Sandstone	85
Shales	10
Concealed	10
Shales, sandy	65
Sandstone, shaly	25
Sandstone, shaly	32
Concealed	30
Sandstone	38
Conglomerate	67
Shale, location of old drift on road, and showing coal 15 inches	35
Sandstone, conglomeratic at bottom	140
Shale, containing coal 2 feet, and possible position of Cumberland Gap coal at Cumberland Gap	10
Sandstone	5
Shale, crushed and bituminous	10
Sandstone	5
Conglomerate	175
Bituminous shale	20
Sandstone	32
Shale, containing plants	6
Coal	$2\frac{2}{12}$
Fire clay	15
Sandstone, greenish at bottom ("approximate base of Lee")	155
Sandstone	60
Shale, olive-green	30



A. OUTCROP OF NAESE SANDSTONE AT TYPE LOCALITY.

Naese Cliff, on Cumberland River, a short distance above the mouth of Hance Creek, from which Naese sandstone receives its name.



B. FOUR OF THE "SEVEN SISTERS."

A well-known locality on Cumberland River. These are outcrops of Naese sandstone, which in this field has been regarded as the top bed of the Lee formation.

	Feet.
Concealed, possibly red shale	50
Yellowish-green conglomerate	38
Shales, green and red, partly hidden	130
Sandstone, greenish	35
Shale, greenish	100
Limestone	20
Shale, greenish	70
Limestone	20
Concealed	105
Limestone	290
Concealed	22
Limestone, cherty	90
Shale, greenish	6
Limestone	5
Shale, red	22
Shale, green	20
Shale, black, Devonian	70
Shale, greenish, and hidden drift of iron-ore mine	50

According to this section, the total thickness of the Lee is 1,187 or 1,367 feet, that of the Mississippian or "Lower Carboniferous" is 1,260 feet, and that of the Devonian black shale is 70 feet.

HANCE FORMATION.

This formation is defined as extending from the top of the Naese sandstone member at its type locality to the bottom of the Lower Hance coal. It has a thickness of about 600 feet. Though it contains two prominent cliff-making sandstones, it is mainly shale. This formation forms most of the valley bottoms and the greater part of the shale bluffs along creeks all over the area. The shale that is so highly folded in the hills around Middlesboro is a part of this formation. As a coal producer the Hance is of minor importance. In the Middlesboro region there has been noted only one workable coal—the Turner coal—which occurs about 200 feet from the top of the formation, and is worked at the Turner mine on Lane Branch of Yellow Creek, just southwest of Middlesboro. In the Black Mountain district three coals in this formation reach a workable thickness locally. About 200 feet or a little less below the Harlan or Lower Hance coal is the Puckett Creek coal, so named because numerous openings have been made on it all along Puckett Creek, in all cases within 150 feet of the bed of the stream. This coal is from 2 to 5 feet thick, but when thick it usually is broken up into benches that are so separated as to be unworkable. About 100 feet below the Puckett Creek coal at the western end of the mountains is the Cranes Creek coal. This is a solid coal whose thickness reaches a maximum of nearly 4 feet, but is usually less than 3 feet. About 100 feet from the bottom of the formation frequently occurs a coal carrying some cannel. At the mouth of Terrys Fork of Wallins Creek this is of workable thickness. It is therefore called the Terrys Fork coal.

Of the sandstones in this formation, one is largely below drainage while the other is probably the most persistent in the field. The latter is called the Cawood sandstone member from the exposures in the bluffs around Cawood post-office. It is there just above drainage level of Martins Fork and at least 80 feet thick. Its tracing may in large part be due to the fact that its position in the hills brings it close to the line of observation on the roads and trails along the stream valleys. It has been traced almost continuously along Martins, Clover, and Poor forks of Cumberland River. In most cases the cliffs are plainly visible from the roads up these forks and are so near together that there is little doubt as to the correlation. Numerous openings on the Harlan coal, 250 feet above, assist in the correlation at doubtful points. Between Harlan and Puckett Creek are other sandstones which form bluffs that are nearly, if not quite, as prominent and which render the tracing of the sandstone more difficult. Over that area an attempt was made to follow the outcrop of the Cawood sandstone along the hillside. Even then the breaks where it does not outcrop are so many and often so long that it could not be traced with certainty from Harlan to Yellow Creek. The sandstone on Puckett Creek, into which it appeared to trace, becomes dominant from that point westward and can be traced without difficulty to Yellow Creek and into the Middlesboro area. This sandstone came the nearest to being a key rock to which all the other formations could be referred with certainty. While it is believed that it has been correctly traced, the degree of certainty is not all that might be hoped for.

About 100 feet above the bottom of the formation is the top of a massive sandstone that makes prominent cliffs at the mouth of Yellow Creek and elsewhere throughout the field where it is above drainage. It is here called the "Yellow Creek sandstone member." This, as well as the Cawood sandstone above and Naese sandstone below, tend to weather out large cavities resembling a magnified honeycomb, so that the name "Bee" rock has been applied to each of these sandstones. (See Pl. VII, *B*.)

MINGO FORMATION.

This formation is named from Mingo Mountain, where in 1903 nine commercial mines were working coals from this formation. It includes the famous Mingo coal, the Sandstone Parting coal worked at several of the mines, and Bennett Fork coal worked at the Bennett Fork mine. In Mingo Mountain the formation has a thickness of about 950 feet. This is divided by the coals mentioned about as follows: From the bottom of the Poplar Lick coal to the bottom of the Sandstone Parting coal, 250 feet; from the bottom of the Sandstone Parting coal to the bottom of the Mingo coal, 250 feet; from the bottom of the Mingo coal to the bottom of the Lower Bennett Fork coal, 450 feet. Northward, toward Pine Mountain, this formation decreases rapidly in thickness. On Little Clear Creek the space from the bottom of the Poplar Lick coal to the bottom of the Mingo coal appears to have decreased to about 350 feet—210 feet from the bottom of the Poplar Lick to the Sandstone Parting coal and 140 feet from the bottom of the latter to the Mingo coal. On Clear Creek the lower space remains the same, while the upper space is reduced to about 160 feet or less. The distance between the bottom of the Mingo coal and the Chenoa cannel coal, which is thought to occupy about the position of the Bennett Fork coal of the Bennett Fork district, is 334 feet according to a drilling on Bear Creek. Such high dips are met with along the south side of Clear Creek that surface measurements between the coals are apt to vary greatly and to be unreliable. This variation is seen in various reports made to the Louisville Property addition to the Harlan coal at the base it contains at least two workable coals, probably more. Of these the Creech coal is thought to occupy about the same stratigraphic position as the Mingo coal, as it occurs about 450 feet below the top of the formation. This coal was discovered in 1901, and knowledge of it was derived almost entirely from facings made under the direction of Mr. Robert Creech in 1902. In Jackson Mountain, where faced by Mr. Creech, it shows as a uniform coal 3 feet 6 inches to 5 feet thick. That it has not been traced outside of that ridge is probably due to lack of exploitation. About 250 feet above the Harlan coal occurs the Kellioka coal, which gives a thick total section, but usually is much split up with partings. Other coals above and below this coal appear to be workable in places, and further exploration may prove them to maintain workable thickness over a considerable area.

At the bottom of the formation occurs the Harlan coal, the most valuable coal yet discovered in the Black Mountains portion of the Cumberland Gap field. The low position of this coal in the hills has led to its being opened up for private or local use at a large number of places and at the same time has taken away the incentive to developing the coals higher in the hills. In general it may be spoken of as a 4-foot coal, though it is often thicker. When much thicker, it is apt to show partings that render the top or bottom less workable, but the thickness of the worked coal in the main bench is about 4 feet, as before. This coal can be traced around the valleys of the three forks of the Cumberland River. It becomes thin in the immediate drainage of Cumberland River and has not been proved on Wallins, Forrester, and lower Puckett creeks. Between Puckett and Yellow creeks it is thought to correspond in position with the lower of two coals, called there the Upper and Lower Hance coals. The Lower Hance coals are thought to be equivalent to the Bennett Fork coals of the Log Mountains district. The Upper Hance coal may correspond with a coal reported at several places as occurring about 30 feet above the Harlan coal, and as reaching a thickness of 3 feet locally.

About 160 feet below the top of the Mingo formation occurs the Puckett sandstone, so named from the prominence of its outcrops around Puckett Creek; it is the sandstone making the so-called "Big Cliffs" on Brownies Ridge, characteristically seen just below the gap between the Blacksnake Branch of Puckett Creek and Blacksnake Branch of Brownies Creek. In places along the west side of Reynolds Mountain, as up Mudlick Branch, it makes vertical cliffs 100 feet high. This sandstone makes fairly prominent cliffs all through the mountains to the east as far as studied, though in places along the upper waters of Martins Fork, the cliffs disappear and the place of the sandstone seems to be entirely taken by shale. On the other hand, in that region a sandstone makes prominent cliffs at nearly the same horizon and in the field was correlated with the Puckett sandstone. Later study seemed to show that this sandstone is stratigraphically about 150 feet or more below the top of the Puckett sandstone, and on account of its making massive cliffs along Slater Fork of Catron Creek it has been called the Slater sandstone. The Creech coal occurs between two thick sandstones, the lower of which is thought to be the representative of the Fork Ridge sandstone of the Log Mountains. It differs from the Fork Ridge sandstone, however, in not being a cliff maker, and in lying close to the Creech coal.

The coarse-grained facies was not noted in Potato Hill Ridge or at most of the places visited on Martins Fork Ridge. It shows poorly in Grays Knob and fairly well in Little and Big Black mountains. From 40 to 60 feet below it in many parts of the field occurs a sandstone that makes bold cliff-like exposures in the heads of many of the streams, notably so around the head of Wallins and Catron creeks. In places it shows a thickness of 80 feet, but a short distance away it may thin down to 10 or 20 feet.

At the bottom of this formation occurs the Wallins Creek coal, and 100 to 120 feet above the Smith 11-foot coal. These coals are supposed to be equivalent to the Poplar Lick and Klondike coals, respectively. The Wallins Creek coal is named from Wallins Creek, around the head of which it occurs, and near which several good measurements were obtained in Hobbs Branch, Trace Fork, and in Sang Branch. These all gave sections showing uniformly about 8½ feet of coal. Somewhat similar coals from 6 to 11 feet thick were found at about the same elevation around the heads of Puckett, Forrester, and Catron creeks, and on Grays Knob, and were reported on Little Black Mountain. At first all these were assumed to be at one horizon. Messrs. McCreath and d'Invilliers, however, reported two coals on Grays Knob, the thickness of the lower of which was 9 feet, while that of the other was 13 feet 6 inches. The upper is said to have been "opened 90 feet vertically higher and immediately above the last-mentioned development."[a]

No such development of two thick coals was found during the present survey either on Grays Knob or elsewhere. At a number of places, however, a coal between 3 and 4 feet thick was found either 150 feet above or 150 feet, more or less, below the thick coal. Then a study of the measurements showed that the distances from the thick coal at about this horizon to the first cliff-making sandstone is about 160 or 320 feet. Evidently there were either two sandstones or two coals. Measurements from the Jesse sandstone to the sandstone below this thick coal gave either about 500 or about 650 feet. These results demonstrated with considerable certainty the existence of two sandstones whose tops were approximately 150 feet apart, each being dominant in part of the area, but one becoming thin where the other was dominant. They seemed to demonstrate also that while in some places, as on Lick Branch of Catron Creek, the 320-foot measurement from the big coal down to the underlying cliff-making sandstone was to the lower of these two sandstones, in other places, as at the old Granville Smith place at the head of Puckett Creek, it was from the coal to the upper of these sandstones, indicating that there were two coals as well as two cliff-making sandstones below this coal. Further study and additional facts seemed to confirm this theory. In this report, therefore, it has been assumed that there are two coals in the Catron formation yielding locally 7 to 8 or more feet of coal. While the thickness of the lower of these, or Wallins Creek coal, is from 7 to 9 feet at a number of places widely scattered over this field, at other places it is less than 4 feet. Ninety to 160 feet above this there is assumed to be another seam, which usually yields only 3 to 4 feet of coal, but in a few places has a total thickness of 11 to 13 feet, as on Grays Knob and on the old Granville Smith place (now the Frost place), at the head of Puckett

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[a] McCreath and d'Invilliers, p. 78.

Creek. This upper coal has, therefore, been called the "Granville Smith 11-foot coal;" or, shortly, the "Smith 11-foot coal," as it has become well known throughout the region by that name.

HIGNITE FORMATION.

The Hignite formation is named from Hignite Creek in the Log Mountains, where it is exposed. There it extends from the bottom of the lower Hignite coal to the top of the Red Spring coal. Barometric measurements on the space between these coals varied from 440 to 540 feet, a majority of the measurements ranging from 440 to 480 feet. Measurements on Bryson Mountain by Mr. J. C. Richardson gave 440 feet; on Puncheon Camp Creek, 500 feet; on Martin Branch of Stony Fork, 480 feet; on Little Clear Creek, 540 feet; on Bean Fork Branch of Yellow Creek, 440 feet; on Bear Creek, 450 feet (the last four by Mr. A. R. Crandall); on Hignite Creek, 440 to 540 feet.

On Hignite Creek a coal partly faced up was taken to be what is generally known in the Log Mountains as the Red Spring coal. It is 5 feet or more thick and occurs immediately above a cliff-making sandstone. What is believed to be the same sandstone (called from its association with this coal the "Red Spring sandstone member of the Hignite formation") was traced as a continuous cliff-making sandstone all along the summit of Log Mountains from Canada Peak to the head of Stony Fork. It makes an amphitheater-like wall at the head of the Middle Fork of Hignite Creek just below the level of the gap. At the bottom of the formation occur the two Hignite coals, 12 feet apart vertically. The upper one is well exposed in the bed of the creek, the lower one in a facing. The bottom of the lower bed, here 3 feet 4 inches thick, forms the bottom of the Hignite formation in the Log Mountains.

The Hignite formation is considered to be equivalent to the rocks that occur in the Black Mountains from the tops of the highest mountain down to the top of the Jesse sandstone. A comparison of spaces from below indicates that this sandstone is equivalent to a massive, often cliff-making sandstone that comes just a few feet below the lower Hignite coal of the Log Mountains. The Jesse sandstone in the Black Mountains is frequently characterized by a scattering of small pebbles whose diameter is seldom more than one-fourth inch and is usually about one-eighth inch. As such pebbles were found only near the mountain summits and at apparently the same distance above the top of the Lee, it was assumed that they occur at the same general horizon. This view was strengthened by the occurrence of the massive Reynolds sandstone above it at a constant interval of about 180 feet, and of other traceable coals and sandstones below also at fairly constant intervals. The highest points of the Black Mountains are from 400 to a little over 500 feet above the top of the Jesse sandstone, so that, as previously suggested, they may reach the horizon of the Bryson formation. Few of the coals in this formation were found in the Black Mountains, and almost no measurements of the coal were obtained. The most prominent member in that region is the Reynolds sandstone. It is the sandstone that is exposed in Hanging Rock of Reynolds Mountain and Pilot Rock of Little Black Mountain. It makes prominent perpendicular cliffs from 50 to 100 feet high along a considerable part of the crests of the Black Mountains. There are other sandstones short distances above and below that in places make almost or quite as prominent cliffs, but in most places the cliffs made by the Reynolds sandstone are more conspicuous than those of the other sandstones within 200 to 300 feet above or below.

BRYSON FORMATION.

This formation occupies the higher tops of the Log Mountains. It may occur on one or two of the highest points in the Black Mountains, as Fox Knob in Potato Hill Ridge, and the higher points of Reynolds Mountain, but it could not be recognized. It is named from Bryson Peak of the Log Mountains, where it is well exposed and where it has been studied better than elsewhere. While it contains one or two coals of workable thickness, such coals have too small an area to be considered profitable. This formation shows a thickness of about 200 feet in most of the higher peaks along the crest of Log Mountains from Bryson Peak to the head of Hignite Creek.

STRUCTURE.

STRUCTURE OF THE APPALACHIAN PROVINCE.

The Appalachian province is structurally a geanticline, whose axis follows the Appalachian Mountains. It seems probable that there have been successive uplifts, and that the axis of movement was transferred northwestward in each case. The earlier movements may have been to the southeast of the present Appalachians, and the land surface thus formed may have furnished a large part of the material at present making up the sedimentary strata west of the Unaka or Great Smoky Mountains. From the Cambrian to the Carboniferous period, there appears to have been little folding, but at or before the close of the Carboniferous the rocks of the Appalachian province yielded to the stresses from the southeast and gave way to form the geanticline at present found there. At the east occur highly disturbed igneous and metamorphic pre-Cambrian rocks. Remnants of the later overlying sediments have in many cases been enfolded with the metamorphosed rocks and thus preserved. But the great mass of the sedimentary rocks lies to the northwest. Those nearest to the Appalachians are the oldest, mainly Cambrian, and present numerous great faults and minor folds. Northwest, toward Cumberland Gap, the faults become less numerous, the folding is less intense, and rocks of later age predominate at the surface. This condition exists across most of the Great Valley. The dips there are almost always to the southeast. Toward the western edge of the Great Valley a broad anticline, sometimes broken with faults, is developed in the Cumberland Gap area. This is known as the Powell Valley anticline. West of this is a broad syncline, a part of which is discussed in this paper. The western edge of this syncline rises to a fault—the Pine Mountain fault. Northwest of Pine Mountain the strata lie nearly horizontally. They dip at a low angle in various directions, but in general toward the southeast.

GENERAL STRUCTURE OF THE CUMBERLAND GAP COAL FIELD.

The Cumberland Gap coal field structurally is a syncline lying between the Pine Mountain fault on the north or northwest and the Powell Valley anticline on the south. The axis of this syncline lies north of the center of the basin, near, but usually a little south of, the Cumberland River. At the west the axis passes through the Log Mountains, between Clear Creek and Stony Fork. It is concealed in the fault belt between Pineville and Cumberland Gap. From the mouth of Yellow Creek to the mouth of Hance Creek it about follows the Cumberland River; as the river turns to the north it continues eastward, crossing Brownies Creek in the neighborhood of Oaks. On Puckett Creek it has not been very definitely located, but in a general way crosses between Blacksnake and Bull branches. Then it turns northward and crosses Saylor and Forrester creeks near their mouths, then eastward, crossing Jesse Creek near the trail between Forrester and Wallins creeks. It crosses Wallins Creek at the mouth of Camp Branch, and Ewing Creek at the mouth of Irving Branch. From Harlan eastward it runs through the center of Big Black Mountain.

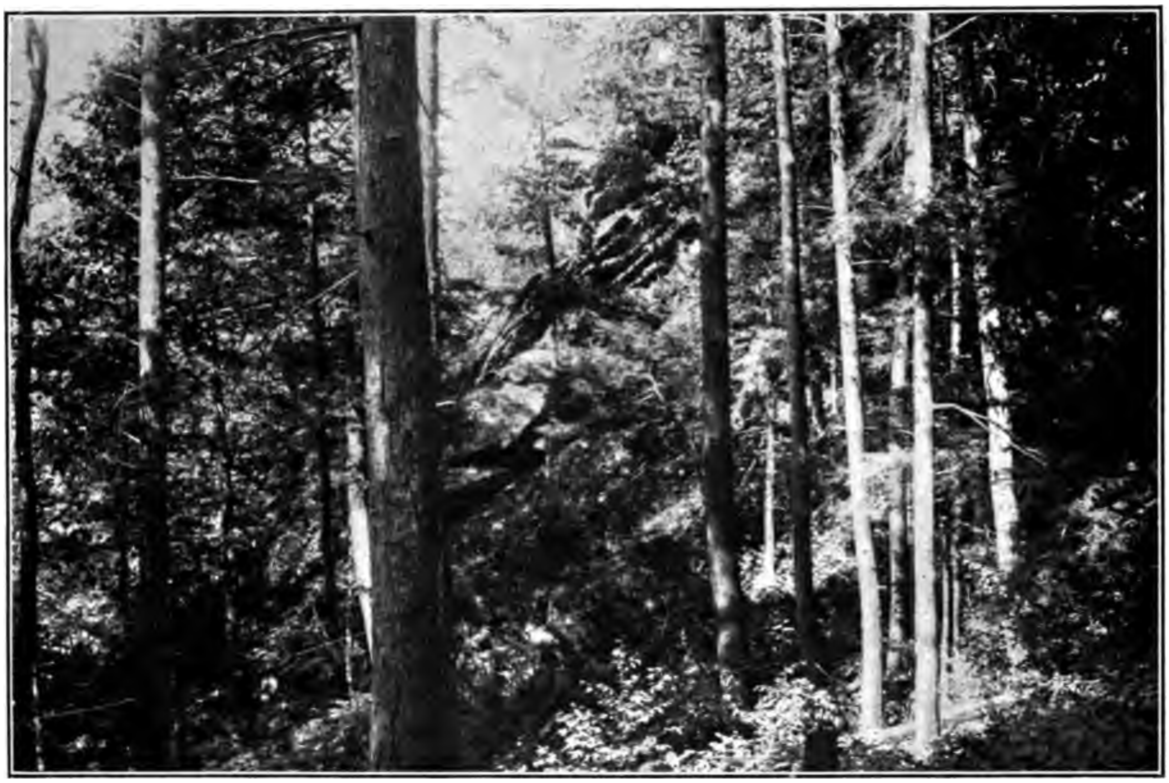
The rise from this axis to the north is irregular, sometimes being but a few feet in the first mile; in other cases the rocks rise sharply from the syncline. Possibly 100 feet in the first mile would be a fair average.

At the foot of Pine Mountain the dip is steeper but variable, ranging from 10° to 65°. Near Chenoa the rocks rise in Pine Mountain with a dip of from 18° to 40°. Near Pineville the dip is from 15° to 30° north of Laurel Hill, from 20° to 35° north of Tanyard Hill, from 10° to 15° near the foot to over 65° near the crest, though it is 45° to 55° along the crest. Bare faces near these measurements seemed to indicate a dip of nearly or quite 90°. Eastward the dip is lower, being seldom above 30°, the south slope of the hill is correspondingly longer.

From the main axis south or southeastward the dip is slight until the foot of Cumberland or Brush Mountain is reached. In the Log Mountain region the dip from the south is less than 100 feet to the mile on the average, though locally it is much higher. On Williams Branch the dip downstream will reach 100 feet or more to the mile. On Hance Creek it averages less than half that; and on Puckett Creek a similar dip of about 50 feet to the mile is found. On Wallins Creek the rise above the axis is about 100 feet to the mile. In the area near the three forks of the Cumberland, there is a rather high dip just south of the axis, then a broad level which includes Catron Creek up to Slater Fork, Martins Fork up to Cawood, Bobs Creek, and Turtle Creek. Up Clover Fork above Ages Creek the strata show an eastward dip of 30 to 40 feet to the mile. On Crummies Creek the rocks are slightly lower than in the broad, flat region just spoken of. In many cases local reversed dips are found, as near Hurst, where a southeast dip is found almost at the foot of Cumberland Mountain. In general this low rise to the south from the main axis continues until the valley at the foot of Cumberland, or Brush, Mountain is reached, as Clear Fork of Yellow Creek, the head of Brownies, Martins Fork, and Cranks Creek. As a rule the hills on the north side of these streams show the rocks lying nearly horizontal, while the south bank, or often the stream bed, shows sandstones with high and, in a few cases, perpendicular dips. Evidently the flexture is a very sharp one. The structure of Cumberland Mountain is considered below. In addition to the longitudinal flexture noted on Clover Fork, a few transverse folds were noted.

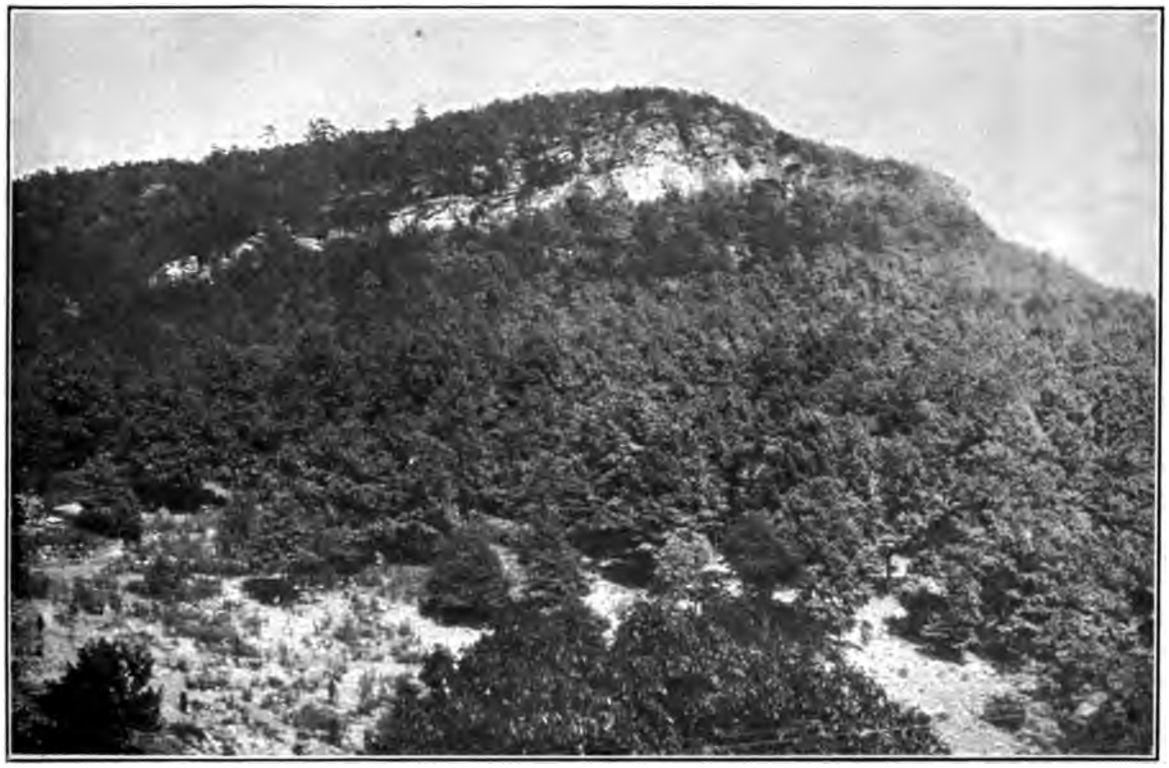
STRUCTURE OF CUMBERLAND MOUNTAIN.

The structure of Cumberland Mountain presents two types (shown on Pl. IX and fig. 10). In one type the mountain is a simple monocline, and the rocks all dip about uniformly at angles of from 25° to 50°. In the other type the rocks are bent sharply upward at the north foot of the mountain at angles closely approaching a right angle, then they are fractured sharply or bent into a nearly horizontal position with a dip of 20° or less. It is of interest that the second type coincides with that portion of the mountains that appears to have been pushed bodily to the north. Beginning at Cumberland Gap the valleys following the foot of the mountain lie a mile or more north of a line from the valley of Little Yellow Creek to the valley of Martins Fork below the end of Brush Mountain. Over much of that distance there is a corresponding northward movement of the escarpment on the southern face. Furthermore, at the southwest end the change from the first type to the second comes sharply at Cumberland Gap and is closely associated with the fault at that point. At the summit of the gap on the west side the rocks are quartzitic sandstones that dip N. 55° W. at an angle of 65°, and no trace of the Newman limestone is found until the limestone quarry is reached at the south foot of the hill, about 1,350 feet south of the gap. On the east side of the gap, the Newman limestone outcrops 80 feet above the saddle, and dips N. 28° W. at angles of from 18° to 25°. On the south side of the gap the line of fault, as shown by fragments of limestone on one side of it and none on the other, has a direction N. 23° W. From the gap northward the fault appears to run out in the form of a nosing, horizontal fold. On the west side of the Harlan road the dip is N. 70° to 85° W. at angles of from 50° to 55°. On the east of that line the dip is N. 5° E. to N. 25° W. at angles of from 15° to 32°. Here then is consistent evidence, along several lines, of differential movement along the Cumberland Mountains; that is, that the part of the Cumberland Mountains between Cumberland Gap and the east end of Brush Mountain has yielded more to the thrust forces from the southeast than the adjacent regions, and the Lee sandstone has there been carried a short distance farther north than to the northeast or southwest. In this case it should not be supposed that there has been an actual northward movement of a mile or more, for a slight elevation combined with the northward movement would throw the Hance shales which determined the line of the valleys well to the north; and, correspondingly, a higher elevation of the Lee sandstone in pre-Cretaceous times combined with the north dip would have allowed it to be eroded much farther to the north. In fact, a slight elevation of the northward-dipping rocks would tend to move the longitudinal valley and the escarpment northward as indicated without actual northward motion on the part of the rocks. The structure, however, indicates that there has been horizontal as well as vertical motion. In the neighborhood of Cumberland Gap it is evident that part of this movement



A. VIEW NEAR BRIERFIELD GAP, CUMBERLAND MOUNTAIN.

Showing Lee sandstone with normal high dip.



B. VIEW OF PINNACLE EAST OF CUMBERLAND GAP.

Showing low dip characteristic of the rocks in the top of Cumberland Mountain from Cumberland Gap to the eastern end of Brush Mountain.

has been by actual shearing along the Cumberland Gap fault. The shape of the escarpment for 2 or 3 miles southwest of Cumberland Gap suggests that that part of Cumberland Mountain was dragged forward at the same time. If so, the rocks just north must have been subjected to torsional stresses. That, it seems quite possible, may account for the highly folded and faulted condition of the shales in the hills immediately about Middlesboro. This folding would also seem to satisfy the demand for a shortening or buckling of the strata in that region to allow the northwestward movement of the Cumberland Mountain. It is quite possible that the folding of the shales that shows at the surface corresponds with a synclinal dip of the massive Lee sandstones, the sandstones being folded while the shales were crushed. Northeast of Cumberland Gap the necessary shortening seems to have been obtained in the main by the change in the shape of the fold. Part of this shortening may have been obtained by the faulted buckle of Rocky Face Mountain. Whether the fault of Rocky Face Mountain joins the Cumberland Gap fault could not be determined, but the evidence was rather against the theory that it does. It is probable, however, that if the two are not parts of a single fault they belong to one fault system and were produced at the same time and by the same force. The Rocky Face Mountain fault will be described below. At the west end of Brush Mountain occurs another interesting fault, or double fault. In this case the two faults appear to meet each other about at right angles, one extending along the strike in Brush Mountain, as though there was a break at the sharp fold where the rocks turn from nearly vertical to nearly horizontal at the top, while the Shillaly Creek fault that meets it at right angles to the strike is followed by Shillaly Creek. As nearly as could be determined the mass of rock occurring within the intersecting faults had dropped down at the corner, the edges of the downthrown block gradually rising until they join the edges from which they were broken. In this case the downthrow has been sufficient to bring down and protect from erosion some rocks that appear to belong to the formations overlying the Lee. The structure as indicated by the dips is shown in fig. 10.

Near Hurst the rocks in places tend to buckle in horizontal planes, so that strata that on either side have dips of 45° to 60° locally are perpendicular or more or less overturned, as though lateral stresses, as well as the main transverse stress, had been induced, as is suggested by diagram b^1, fig. 10.

ROCKY FACE MOUNTAIN FAULT.

Rocky Face Mountain (fig. 11) as shown on the map is a north-south ridge with unusually narrow crest and steep flanks. Structurally it is a faulted arch with downthrow on the west. The rocks involved are the massive Lee sandstones and conglomerates. The fault appears to become an anticline at each end and to nose out rapidly. At the north end the fold shows plainly on the north side of Cannon Creek, the west limb of the anticline being nearly perpendicular and the east limb dipping N. 82° E. at an angle of 30°. The conglomerate appears in the bed of Cannon Creek and is slightly faulted. The faulting probably begins at the creek. The upthrust side rises rapidly, attaining an elevation of over 2,500 feet. The upthrust strata acquire a dip of from 80° to 87°, the change from a dip of 25° to one of 80° at the foot of the mountain taking place in a few feet. At the crest the rocks bend sharply almost to the horizontal and then are sharply cut off, presenting an almost perpendicular face several hundred feet high. At the south end the structure is not entirely clear, but apparently the fault changes to an anticline before the south end of the mountain is reached, and fairly low dips both southwest and southeast indicate a nosing out of the anticline. The disturbance crosses Yellow Creek, but does not appear to extend far into Dark Ridge. These features are shown in fig. 11. It seems possible to estimate roughly the amount of north-south shortening that has taken place in the buckling or arching seen in Rocky Face Mountain. An estimate made by graphically plotting to scale the facts as known shows a shortening just along the line

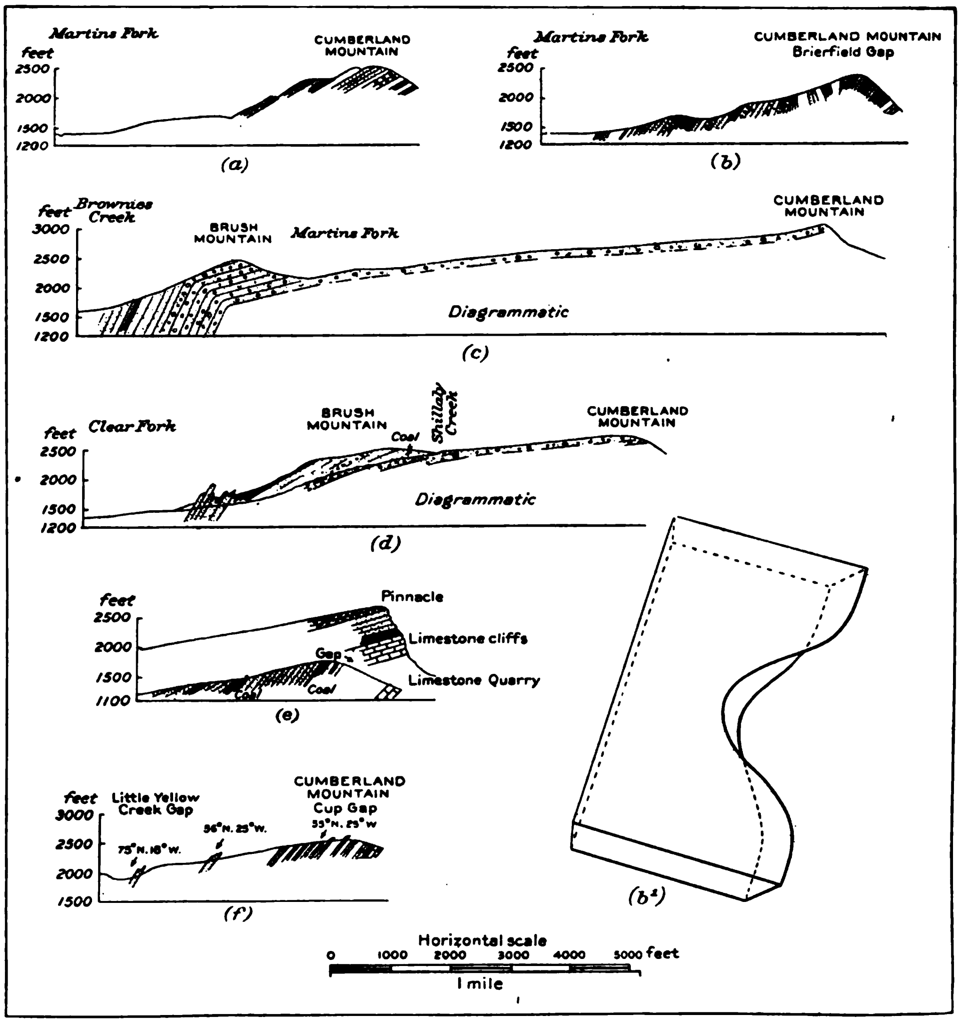


FIG. 10.—Sections showing structure of Cumberland Mountain: (b^1 explains dips in b).

of fracture of from 1,200 to 2,000 feet. Such a fold probably does not extend to any great depth. Below the arching Lee sandstone the Pennington shale has probably been folded up much as the Hance shales have been at Middlesboro. In the case of the Middlesboro area it would seem possible that there exists a local synclinal fold in the massive Lee sandstone corresponding in shape to the Rocky Face Mountain arch, but reversed.

In Volume III, new series, of the reports of the Kentucky Geological Survey, Professor Shaler argues that the Pine Mountain and other faults of this region were formed recently, especially when compared with such features as the Powell Valley anticline. The basis for this argument is mainly the small amount of erosion that has taken place since the faults were formed. Thus, in the case of Pine Mountain, the fault scarp has retreated but little from the original plane of faulting, while the Cumberland Mountain scarp has retreated several miles from the axis of the Powell Valley anticline. In all this no account was taken of the Cumberland peneplain. This peneplain is believed to have been the last stage of a cycle whose end came near the close of the Cretaceous. With that in mind it is evident that the present Pine Mountain was below drainage from the Carboniferous nearly to the end of the Cretaceous. On the other hand the anticlinal structure carried the Lee sandstone east of Cumberland Mountain well above the level of the peneplain, where it was subject to erosion, and it is more than probable that a large share of the northwestward cutting of the Lee sandstone of Cumberland Mountain took place during the production of the peneplain. That the Pine Mountain fault has not been produced since Cretaceous time is evident from the fact that Pine Mountain, resulting from it, was leveled off in pre-Cretaceous time. For the same reason it is evident that

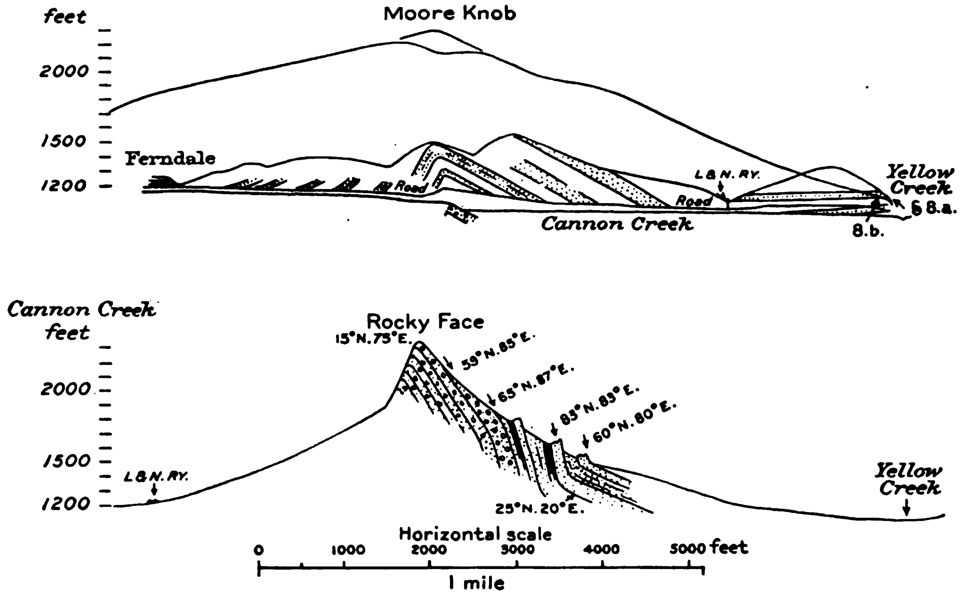


FIG. 11.—Structure of Rocky Face Mountain.

no large movement along Pine Mountain fault has taken place in post-Cretaceous time, though small movement may well have occurred. That such movements have taken place in the Yellow Creek Valley appears from the discussion of the Middlesboro plain in the section on Geography. As stated there, if erosion below the 2,500-foot level did not begin here until nearly the end of Cretaceous time, erosion that reached down to the present drainage levels must have been comparatively recent. If, as stated above, there exists at Middlesboro a local synclinal fold in the Lee sandstone, it is possible that a slight further yielding would deepen it and might locally depress the land there, bringing the old drainage lines below their former level of outflow and allowing the silting up of the basin thus formed. In this case, while sinking at Middlesboro is certain, there may also have been a movement along the fault face at Rocky Face Mountain. Such a movement would be closely related to a subsidence at Middlesboro, the two movements, if both occurred, being but two expressions of a single readjustment.

There is slight evidence of a still more recent movement of similar character, though of slight amount in the dip of the Arthur Heights gradation plain from north to south. This dip amounts to about 20 feet to the mile. It can not be asserted that this dip is not due to the differential effects of erosion, but it suggests that there has been in comparatively recent time a noticeable tilting of the rocks with sinking at the south or uplift to the north.

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The first stage of the investigation of the coal resources of any area is usually confined to finding and measuring a few scattered outcrops of the coals. This work shows, first, that coal is present and may indicate whether it is workable. Such data are usually obtained in a more or less rapid reconnaissance trip. With such data it is not usually possible to make more than guesses at the correlations of the coals, and little or no idea can be obtained of the persistence or reliability of the beds. If the structure be very simple, often a very fair idea of its general features may be obtained in such a trip, though minor details that are apt to escape observation usually render any attempted correlations unreliable. If the structure is obscure or complicated such a trip will reveal little else than that fact. The report of the trip will consist of little more than a transcription of the field observations following the itinerary of the journey. If a map is published it will usually only show the route traversed and the location of points mentioned in the text.

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The third stage of exploration, which usually immediately precedes or accompanies active exploitation, is that in which the knowledge to be derived as above is augmented by drillings, test shafts, and more or less continuous facings. In a region like this the latter method is the one usually followed. Some drain or stream which gives clean exposures over much of its extent is followed, and wherever the bed is hidden by talus, vertical cuts are made on the side banks. Springs that suggest that they come from coal are dug into, and the coal, if there, exposed. In many cases where the distance of a given coal above or below a sandstone that can be followed is known, measurements are made up or down the slope from the sandstone at favorable places and the face of the hill boldly dug into for as great a vertical distance as may be necessary until the bloom of the coal is found; then that is followed until the full thickness of the coal is exposed in a fairly unweathered condition, with its roof shale above and underclay below. Facings of this kind are especially made when it is desired to map accurately and to "prove" the workability of any particular coal bed. Our to 200 feet above or below the true level. If, in addition to the elevation above the mouth of the creek, other elevations had been given, such as the elevation above or below some recognizable point on the creek, as the forks, or the foot of a prominent cliff (and it is seldom that such a point can not be found within 300 feet vertically of any coal), the limit of error in barometer reading is largely eliminated. In many cases coals referred to some near-by landmark, either stratigraphic or geographic, may be located without a barometer. Because the companies interested in the Middlesboro area did not possess this information, it was not possible to work into the observed sections much of the data obtained by means of special facings, etc. To illustrate: The Red Spring coal, a good 5-foot coal, known only through facings, was not only not seen, but, as the barometer only was used, its stratigraphic position—that is, its position relative to a prominent sandstone occurring at about its reported elevation above the streams below—was not determined with certainty. Such information is desirable not only in the determination of the position of old datum points, but in checking other data in mapping, in working out the stratigraphy, or in testing the correctness of assumed correlations. For the same reason, in this report the attempt is usually made to tie the coal data, if high in the hill to some prominent cliff or other recognizable feature.

Before the present work, the Black Mountains have been mainly in the first stage of development. Partial exception should be made of the area between Brownies Creek and Yellow Creek and the north end of Jackson Mountain. In the area mentioned, Mr. Robert Creech has had a large number of facings made on lands recently purchased by him and Mr. Thomas Asher. These have not been carried to as great completeness as some of the work in Log Mountains, as the facings have usually been confined to a few good beds. Knowledge of this part of the field is much more complete than of the districts farther east.

Because of the completeness of the data in the Log Mountains the description of this field will begin at the west and go to the east. A comparison of the data given might at first sight lead to the conclusion that the Log Mountains contained many more workable coals than the Black Mountains. However, 90 per cent of our knowledge of the workable coals of the Log Mountains comes from mines or artificial facings on the coals, neither of which exist in the Black Mountains area, so the difference is not to be wondered at. Thus, of the workable coals in the Log Mountains, the Red Spring coal was not measured by us; two feet of what was supposed to be it was seen, and a coal bloom supposed to be it was noted in two or three places. These data alone do not warrant placing it among the possibly workable coals. The Lower Hignite coal was seen and measured at three places, none of which were natural outcrops. In like manner only a single natural outcrop that could be completely measured was seen of either the Klondike, Poplar Lick, or Mingo coals, so that had there been no mines or artificial facing on these coals the area might have been examined without their workability being suspected.

For convenience in discussion the map of the area as a whole has been cut into sections that would conveniently go on a page inserted in the text. These page-size portions of the map and the detailed study of the field are here taken up by such districts. In dividing the map the attempt was made to divide it so that each of these artificial districts would more or less nearly constitute a natural district—that is, so that the coal in the area of one district would lie more or less nearly in a single body. (See footnote next page.)

In each district it is, then, planned to discuss, first, the geography of the district; second, the stratigraphy; third, the coals, considering their detailed sections, and discussing under each coal the persistence of its minor features, its average thickness, its roof and floor, and its probable workability; fourth, the structure of the field and the position of the coals and key rocks in the hills.

The graphic method of representing the coals is used. The figures on the right side represent the thickness of the benches, those on the left the thickness of the partings, or bone coal. At the bottom are summed up the total thickness of partings and coal benches and total thickness of seam. In some cases the part of the seam that is workable is indicated, as many of the thick seams are only workable in part, due to partings or poor quality. In actual experience it is often necessary to leave part of the good coal for floor or roof. It is not always possible ahead of actual mining to know when the character of the roof or floor will necessitate such action. The accompanying figure will serve to show the meaning of the symbols used in the sections. The scale of all the coal sections is, 1 inch equals 5 feet; of the columnar sections, 1 inch equals 300 feet. In the columnar sections an attempt has been made to indicate the topographic results obtained by the weathering of the different parts of the column, especially as regards the cliff-producing beds.

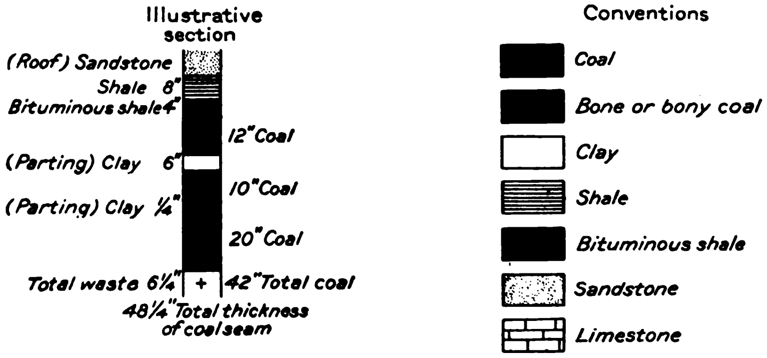


FIG. 12.—Illustrative coal section and conventions used on columnar sections.

In order to show as nearly as possible the exact location of the points about which data are given, each coal outcrop or mine was given a number in the notebooks and the corresponding number was placed on the map. These numbers are placed conspicuously above the coal sections on the plates of coal sections. The same numbers appear in parentheses in the body of the text. They begin on Little Yellow Creek and in general run around the mountains from the southwest corner to the northeast corner and back. From 1 to 206 are in the Bennett Fork district; from 221 to 426 in Stony Fork-Clear Creek district; from 450 to 1,238 the numbers become larger from west to east, the highest numbers being east of Harlan, but as the division into districts was made after the numbering the numbers are not grouped by districts.

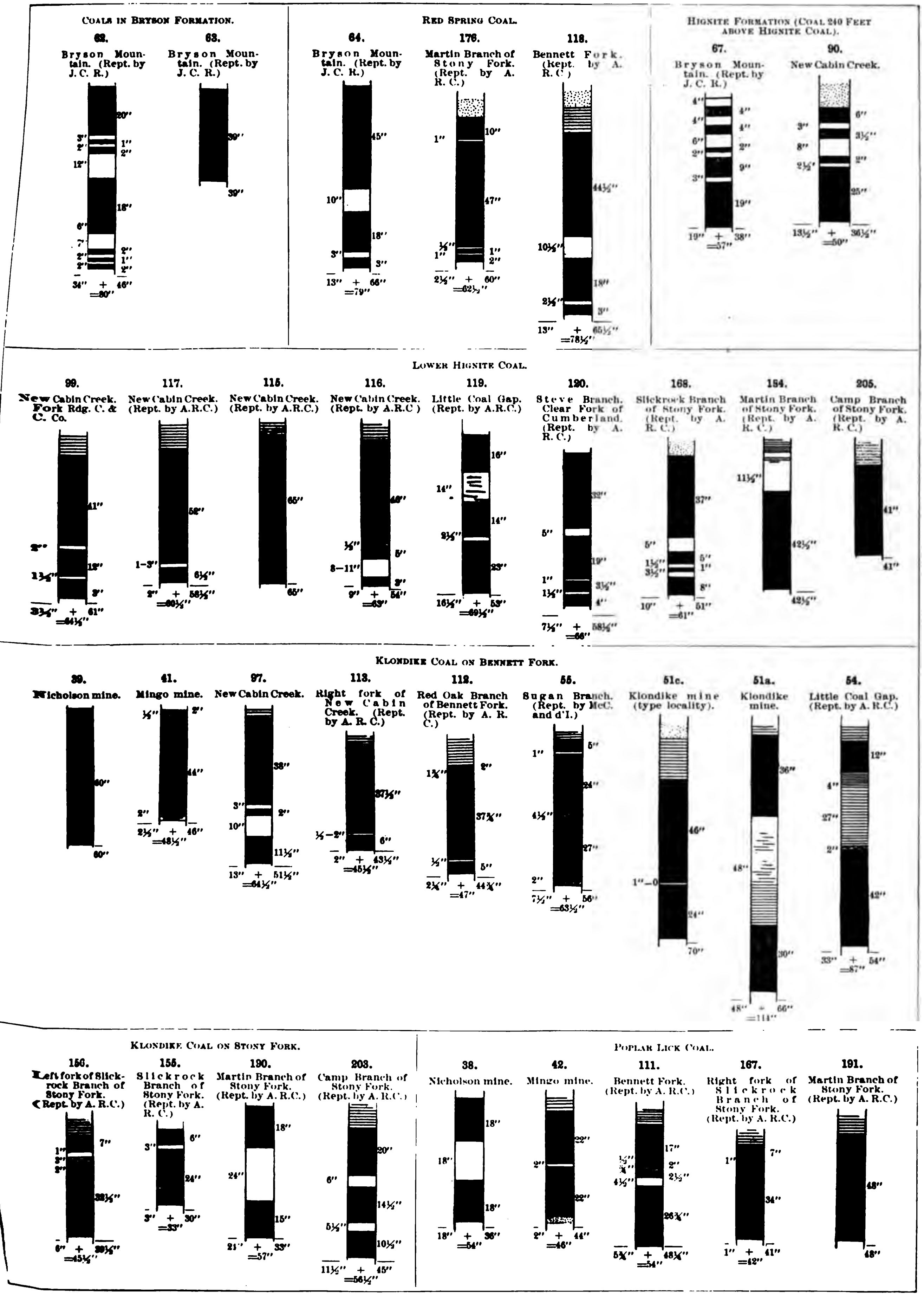
Condensed section of principal coals and intervals in Bennett Fork district.

	Feet.
Bryson formation.	
Hignite formation:	
Red Spring coal at top	5
Interval	440
Lower Hignite coal at bottom	5
Catron formation:	
Interval	300
Klondike coal	5
Interval	50
Poplar Lick coal	4
Mingo formation:	
Interval	230
Sandstone Parting coal	4
Interval	285
Mingo coal	5
Interval	40
Fork Ridge sandstone, key rock	40
Interval	360
Upper Bennett Fork coal	4
Interval	8–16
Lower Bennett Fork coal	4
Hance formation:	
Interval	200
Turner coal	4
Interval	400?

The following columnar section has been worked out from two sections of the coals and intervals in Bryson Mountain, one of which was obtained by Mr. J. C. Richardson and the other by Mr. A. R. Crandall. The two sections are identical in most features, though each contains some coals omitted in the other. The measurements of the intervals are given from the section by Mr. Crandall, in the State Mine Inspector's Report for 1893.

Section of Bryson Mountain.

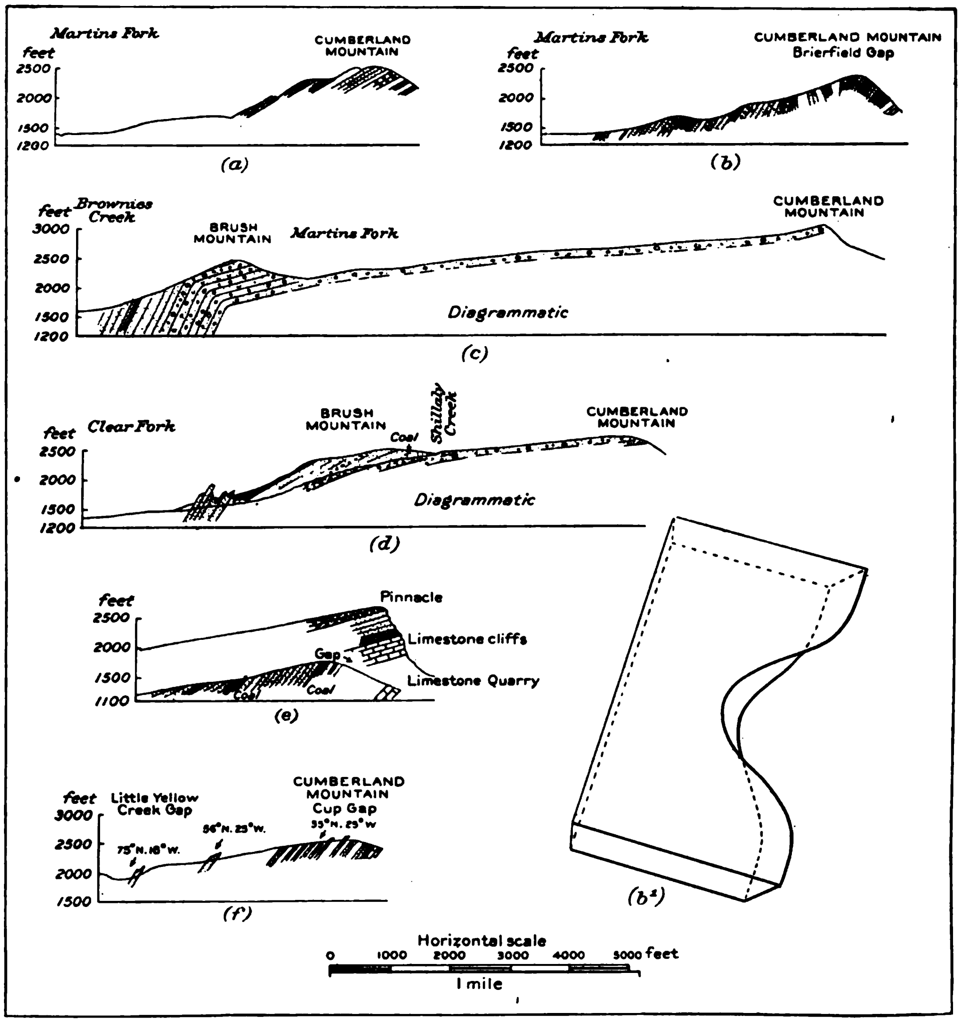
No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	in.	Ft.	in.
	Slope	60	0	60	0
61	Coal and clay	1	3	61	3
	Interval	40	0	100	3
62	Coal	6	8	107	11
	Interval	40	0	147	11
63	Coal	3	3	151	2
	Interval	12	0	163	2
63a	Coal	10	3	163	10
	Interval	80	0	243	10
64	Coal, Red Spring	6	7	250	5
	Interval	20	0	270	5


COALS IN BRYSON FORMATION.
62. Bryson Mountain. (Rept. by J. C. R.)
34" + 46" =80"
63. Bryson Mountain. (Rept. by J. C. R.)
39"
RED SPRING COAL.
64. Bryson Mountain. (Rept. by J. C. R.)
13" + 66" =79"
176. Martin Branch of Stony Fork. (Rept. by A. R. C.)
2½" + 60" =62½"
118. Bennett Fork. (Rept. by A. R. C.)
13" + 65½" =78½"
HIGNITE FORMATION (COAL 240 FEET ABOVE HIGNITE COAL).
67. Bryson Mountain. (Rept. by J. C. R.)
19" + 38" =57"
90. New Cabin Creek.
13½" + 36½" =50"
LOWER HIGNITE COAL.
99. New Cabin Creek. Fork Rdg. C. & C. Co.
3½" + 61" =64½"
117. New Cabin Creek. (Rept. by A.R.C.)
2" + 58½" =60½"
115. New Cabin Creek. (Rept. by A.R.C.)
65"
116. New Cabin Creek. (Rept. by A.R.C.)
9" + 54" =63"
119. Little Coal Gap. (Rept. by A.R.C.)
16½" + 53" =69½"
120. Steve Branch. Clear Fork of Cumberland. (Rept. by A. R. C.)
7½" + 58½" =66"
168. Slickrock Branch of Stony Fork. (Rept. by A. R. C.)
10" + 51" =61"
184. Martin Branch of Stony Fork. (Rept. by A. R. C.)
42½"
205. Camp Branch of Stony Fork. (Rept. by A. R. C.)
41"
KLONDIKE COAL ON BENNETT FORK.
39. Nicholson mine.
60"
41. Mingo mine.
2½" + 46" =48½"
97. New Cabin Creek.
13" + 51½" =64½"
113. Right fork of New Cabin Creek. (Rept. by A. R. C.)
2" + 43½" =45½"
112. Red Oak Branch of Bennett Fork. (Rept. by A. R. C.)
2½" + 44½" =47"
55. Sugan Branch. (Rept. by McC. and d'I.)
7½" + 56" =63½"
51c. Klondike mine (type locality).
70"
51a. Klondike mine.
48" + 66" =114"
54. Little Coal Gap. (Rept. by A. R. C.)
33" + 54" =87"
KLONDIKE COAL ON STONY FORK.
150. Left fork of Slickrock Branch of Stony Fork. (Rept. by A. R. C.)
6" + 39½" =45½"
155. Slickrock Branch of Stony Fork. (Rept. by A. R. C.)
3" + 30" =33"
190. Martin Branch of Stony Fork. (Rept. by A. R. C.)
21" + 33" =57"
203. Camp Branch of Stony Fork. (Rept. by A. R. C.)
11½" + 45" =56½"
POPLAR LICK COAL.
38. Nicholson mine.
18" + 36" =54"
42. Mingo mine.
2" + 44" =46"
111. Bennett Fork. (Rept. by A. R. C.)
5½" + 48½" =54"
167. Right fork of Slickrock Branch of Stony Fork. (Rept. by A. R. C.)
1" + 41" =42"
191. Martin Branch of Stony Fork. (Rept. by A. R. C.)
48"

SECTIONS OF UPPER COALS, BENNETT FORK DISTRICT.

Scale: 1 inch = 5 feet.

dip of 25° to one of 80° at the foot of the mountain taking place in a few feet. At the crest the rocks bend sharply almost to the horizontal and then are sharply cut off, presenting an almost perpendicular face several hundred feet high. At the south end the structure is not entirely clear, but apparently the fault changes to an anticline before the south end of the mountain is reached, and fairly low dips both southwest and southeast indicate a nosing out of the anticline. The disturbance crosses Yellow Creek, but does not appear to extend far into Dark Ridge. These features are shown in fig. 11. It seems possible to estimate roughly the amount of north-south shortening that has taken place in the buckling or arching seen in Rocky Face Mountain. An estimate made by graphically plotting to scale the facts as known shows a shortening just along the line



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In exploration in the first stage little attention is paid to the topography. In the second stage it is necessary that there be available a topographic map of the area under investigation, or that a topographic map of more or less accuracy be constructed at the same time that the geologic work is done. In the third stage practically all datum points are leveled to. In the first stage little or no attention is given to the structure, and often very little to the stratigraphy, as a whole or in any detail. In the second stage all the major features, both of the structure and stratigraphy, are worked out and as large a share of the minor features as the time will allow. In the third stage an attempt is made to obtain both the structure and stratigraphy in detail and without breaks in the continuity—the stratigraphy by deep borings and long vertical facings, the structure by boring to a particular bed or facings on a particular bed, or by the instrumental following of the outcrop of some key rock.

In the Cumberland Gap coal field, up to the opening up of the field west of Middlesboro, exploration of a public or semipublic nature had been only of the first stage. Of this character is the report of an examination of this area made in 1887 by Messrs. McCreath and d'Invilliers for the Louisville and Nashville Railroad. Since the opening up of the field about Middlesboro much of the exploration in the Log Mountains has reached the third stage. Both the American Association Incorporated and the Louisville Property Company (formerly the Log Mountain Coal, Coke, and Timber Company), with large interests in the Log Mountains, have had extensive facings done at a large number of places in those mountains, so that it is probable that there are to-day sections of all the coal beds to be found along the several streams examined. Much of this work was done under the supervision of Mr. A. R. Crandall, insuring its reliability. Probably much more work has been done under the direction of Mr. J. C. Richardson for the first company and of Mr. J. R. Justice for the second company of equally or more accurate character, because largely based on actual levels. In this latter work may be mentioned the preparation of a detailed map of the Poplar Lick coal in Canada Ridge, with exact levels on a large number of facings on the coal. In addition to data of this character, there is now available a large amount of data obtainable from the mines being operated along Bennett Fork and being opened along Stony Fork. Unfortunately no one horizon has been faced or traced uniformly throughout this portion of the field, nor have the coal data been compared to stratigraphic bench marks in such a way that now, when most of the facings have disappeared, it is possible to locate accurately the position or elevations of datum points. For example, Mr. Crandall's work may give the thickness of a coal reported at 1,300 feet above the mouth of a given stream. If the data were originally obtained with a barometer, the chances are that later another barometer may not give the same reading within 50 or 100 feet of the actual position of the coal; if the first determination was by spirit level or stadia, the position may be later determined accurately by a repetition of the instrumental leveling, but only approximately by the barometer, and the datum point may be sought at an elevation of from 10 to 200 feet above or below the true level. If, in addition to the elevation above the mouth of the creek, other elevations had been given, such as the elevation above or below some recognizable point on the creek, as the forks, or the foot of a prominent cliff (and it is seldom that such a point can not be found within 300 feet vertically of any coal), the limit of error in barometer reading is largely eliminated. In many cases coals referred to some near-by landmark, either stratigraphic or geographic, may be located without a barometer. Because the companies interested in the Middlesboro area did not possess this information, it was not possible to work into the observed sections much of the data obtained by means of special facings, etc. To illustrate: The Red Spring coal, a good 5-foot coal, known only through facings, was not only not seen, but, as the barometer only was used, its stratigraphic position—that is, its position relative to a prominent sandstone occurring at about its reported elevation above the streams below—was not determined with certainty. Such information is desirable not only in the determination of the position of old datum points, but in checking other data in mapping, in working out the stratigraphy, or in testing the correctness of assumed correlations. For the same reason, in this report the attempt is usually made to tie the coal data, if high in the hill to some prominent cliff or other recognizable feature.

Before the present work, the Black Mountains have been mainly in the first stage of development. Partial exception should be made of the area between Brownies Creek and Yellow Creek and the north end of Jackson Mountain. In the area mentioned, Mr. Robert Creech has had a large number of facings made on lands recently purchased by him and Mr. Thomas Asher. These have not been carried to as great completeness as some of the work in Log Mountains, as the facings have usually been confined to a few good beds. Knowledge of this part of the field is much more complete than of the districts farther east.

Because of the completeness of the data in the Log Mountains the description of this field will begin at the west and go to the east. A comparison of the data given might at first sight lead to the conclusion that the Log Mountains contained many more workable coals than the Black Mountains. However, 90 per cent of our knowledge of the workable coals of the Log Mountains comes from mines or artificial facings on the coals, neither of which exist in the Black Mountains area, so the difference is not to be wondered at. Thus, of the workable coals in the Log Mountains, the Red Spring coal was not measured by us; two feet of what was supposed to be it was seen, and a coal bloom supposed to be it was noted in two or three places. These data alone do not warrant placing it among the possibly workable coals. The Lower Hignite coal was seen and measured at three places, none of which were natural outcrops. In like manner only a single natural outcrop that could be completely measured was seen of either the Klondike, Poplar Lick, or Mingo coals, so that had there been no mines or artificial facing on these coals the area might have been examined without their workability being suspected.

For convenience in discussion the map of the area as a whole has been cut into sections that would conveniently go on a page inserted in the text. These page-size portions of the map and the detailed study of the field are here taken up by such districts. In dividing the map the attempt was made to divide it so that each of these artificial districts would more or less nearly constitute a natural district—that is, so that the coal in the area of one district would lie more or less nearly in a single body. (See footnote next page.)

In each district it is, then, planned to discuss, first, the geography of the district; second, the stratigraphy; third, the coals, considering their detailed sections, and discussing under each coal the persistence of its minor features, its average thickness, its roof and floor, and its probable workability; fourth, the structure of the field and the position of the coals and key rocks in the hills.

The graphic method of representing the coals is used. The figures on the right side represent the thickness of the benches, those on the left the thickness of the partings, or bone coal. At the bottom are summed up the total thickness of partings and coal benches and total thickness of seam. In some cases the part of the seam that is workable is indicated, as many of the thick seams are only workable in part, due to partings or poor quality. In actual experience it is often necessary to leave part of the good coal for floor or roof. It is not always possible ahead of actual mining to know when the character of the roof or floor will necessitate such action. The accompanying figure will serve to show the meaning of the symbols used in the sections. The scale of all the coal sections is, 1 inch equals 5 feet; of the columnar sections, 1 inch equals 300 feet. In the columnar sections an attempt has been made to indicate the topographic results obtained by the weathering of the different parts of the column, especially as regards the cliff-producing beds.

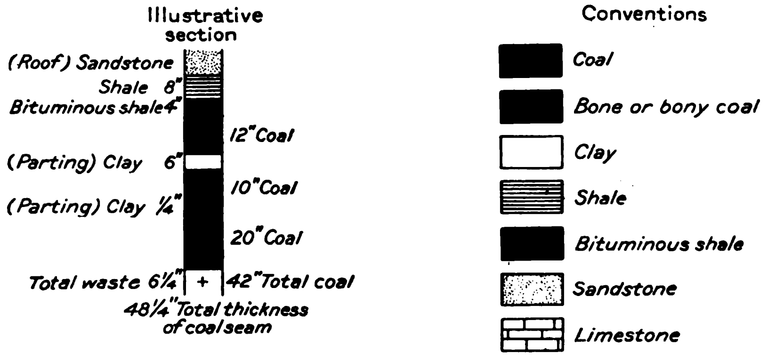


FIG. 12.—Illustrative coal section and conventions used on columnar sections.

In order to show as nearly as possible the exact location of the points about which data are given, each coal outcrop or mine was given a number in the notebooks and the corresponding number was placed on the map. These numbers are placed conspicuously above the coal sections on the plates of coal sections. The same numbers appear in parentheses in the body of the text. They begin on Little Yellow Creek and in general run around the mountains from the southwest corner to the northeast corner and back. From 1 to 206 are in the Bennett Fork district; from 221 to 426 in Stony Fork-Clear Creek district; from 450 to 1,238 the numbers become larger from west to east, the highest numbers being east of Harlan, but as the division into districts was made after the numbering the numbers are not grouped by districts.

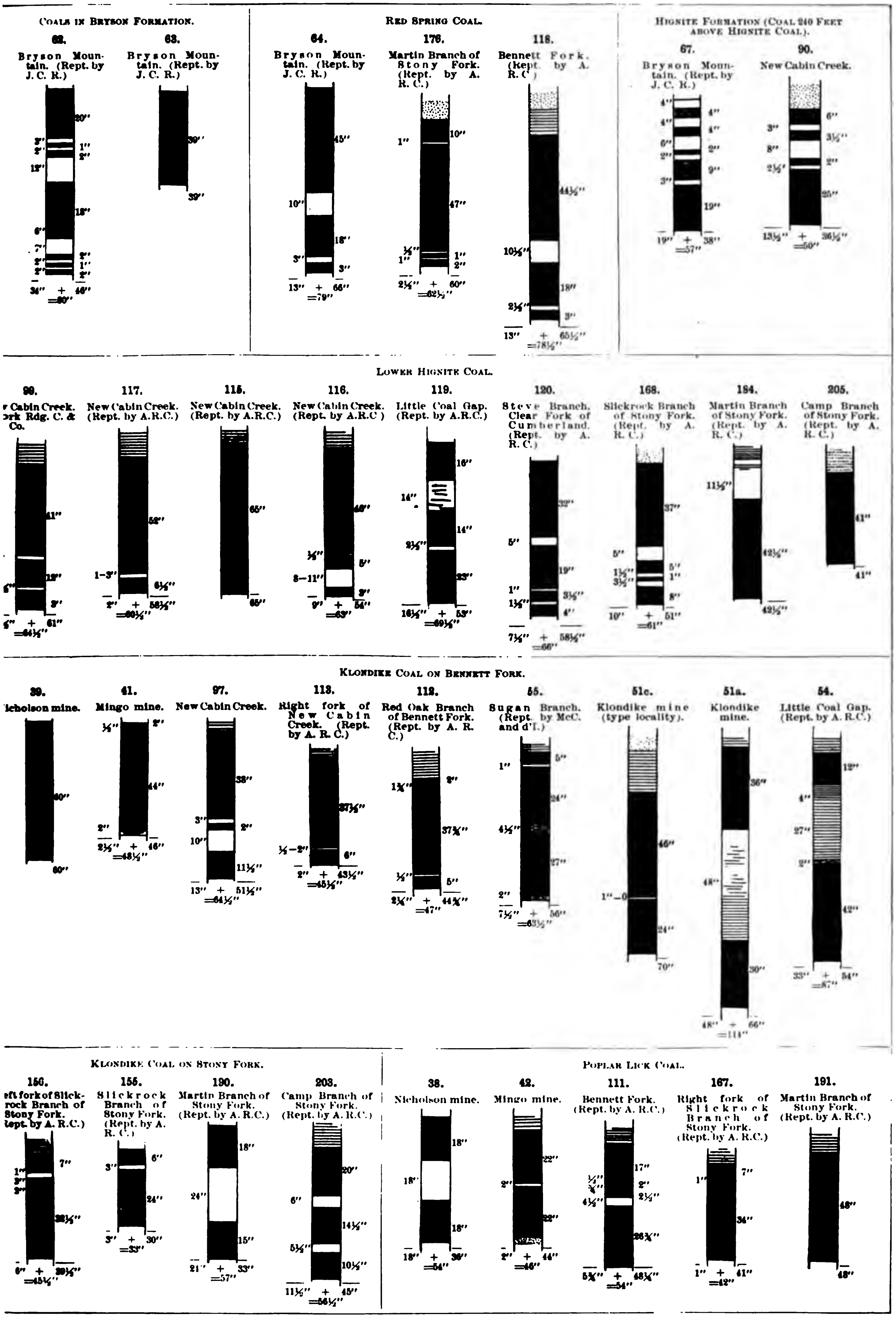
Condensed section of principal coals and intervals in Bennett Fork district.

	Feet.
Bryson formation.	
Hignite formation:	
Red Spring coal at top	5
Interval	440
Lower Hignite coal at bottom	5
Catron formation:	
Interval	300
Klondike coal	5
Interval	50
Poplar Lick coal	4
Mingo formation:	
Interval	230
Sandstone Parting coal	4
Interval	285
Mingo coal	5
Interval	40
Fork Ridge sandstone, key rock	40
Interval	360
Upper Bennett Fork coal	4
Interval	8–16
Lower Bennett Fork coal	4
Hance formation:	
Interval	200
Turner coal	4
Interval	400?

The following columnar section has been worked out from two sections of the coals and intervals in Bryson Mountain, one of which was obtained by Mr. J. C. Richardson and the other by Mr. A. R. Crandall. The two sections are identical in most features, though each contains some coals omitted in the other. The measurements of the intervals are given from the section by Mr. Crandall, in the State Mine Inspector's Report for 1893.

Section of Bryson Mountain.

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
	Slope	60	0	60	0
61	Coal and clay	1	3	61	3
	Interval	40	0	100	3
62	Coal	6	8	107	11
	Interval	40	0	147	11
63	Coal	3	3	151	2
	Interval	12	0	163	2
63*a*	Coal	10	3	163	10
	Interval	80	0	243	10
64	Coal, Red Spring	6	7	250	5
	Interval	20	0	270	5


Coals in Bryson Formation.
62. Bryson Mountain. (Rept. by J. C. R.)
63. Bryson Mountain. (Rept. by J. C. R.)
Red Spring Coal.
64. Bryson Mountain. (Rept. by J. C. R.)
176. Martin Branch of Stony Fork. (Rept. by A. R. C.)
118. Bennett Fork. (Rept. by A. R. C.)
Hignite Formation (Coal 240 Feet above Hignite Coal).
67. Bryson Mountain. (Rept. by J. C. R.)
90. New Cabin Creek.
Lower Hignite Coal.
99. r Cabin Creek. ork Rdg. C. & Co.
117. New Cabin Creek. (Rept. by A.R.C.)
115. New Cabin Creek. (Rept. by A.R.C.)
116. New Cabin Creek. (Rept. by A.R.C.)
119. Little Coal Gap. (Rept. by A.R.C.)
120. Steve Branch. Clear Fork of Cumberland. (Rept. by A. R. C.)
168. Slickrock Branch of Stony Fork. (Rept. by A. R. C.)
184. Martin Branch of Stony Fork. (Rept. by A. R. C.)
205. Camp Branch of Stony Fork. (Rept. by A. R. C.)
Klondike Coal on Bennett Fork.
39. icholson mine.
41. Mingo mine.
97. New Cabin Creek.
113. Right fork of New Cabin Creek. (Rept. by A. R. C.)
112. Red Oak Branch of Bennett Fork. (Rept. by A. R. C.)
55. Sugan Branch. (Rept. by McC. and d'I.)
51c. Klondike mine (type locality).
51a. Klondike mine.
54. Little Coal Gap. (Rept. by A. R. C.)
Klondike Coal on Stony Fork.
150. eft fork of Slickrock Branch of Stony Fork. ept. by A. R. C.)
155. Slickrock Branch of Stony Fork. (Rept. by A. R. C.)
190. Martin Branch of Stony Fork. (Rept. by A. R. C.)
203. Camp Branch of Stony Fork. (Rept. by A. R. C.)
Poplar Lick Coal.
38. Nicholson mine.
42. Mingo mine.
111. Bennett Fork. (Rept. by A. R. C.)
167. Right fork of Slickrock Branch of Stony Fork. (Rept. by A. R. C.)
191. Martin Branch of Stony Fork. (Rept. by A. R. C.)

SECTIONS OF UPPER COALS, BENNETT FORK DISTRICT.

Scale: 1 inch=5 feet.

Section of Bryson Mountain—Continued.

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
65	Coal		6	270	11
	Interval	100	0	370	11
66	Coal		8	371	7
	Interval, sandstone and shale	70	0	441	7
67	Coal, with parting	4	9	446	4
	Interval, shale	44	0	490	4
68	Coal	1	0	491	4
	Interval, shale	44	0	535	4
68*a*	Cannel and slate		9	536	1
	Interval (?)	5	0	541	1
69	Coal		2	541	3
	Interval (?)	5	0	546	3
70	Coal	1	2	547	5
	Interval, shale, shaly sandstone	70	0	617	5
71	Coal	1	6	618	11
	Interval	10	0	628	11
71*a*	Coal, thin				
	Interval	4	0	632	11
71*b*	Coal, thin				
	Interval	20	0	652	11
71*c*	Coal, thin				
	Interval	12	0	664	11
71*d*	Coal, thin				
	Interval	14	0	678	11
72	Coal, Lower Hignite	5	1	684	0
	Interval	10	0	694	0
72*a*	Coal, thin				
	Interval	70	0	764	0
73	Coal		8	764	8
	Interval	54	0	818	8
74	Coal	1	8	820	4
	Interval	24	0	844	4
75	Coal	2	9	847	1
	Interval	6	0	853	1
76	Coal		10	853	11
	Interval	8	0	861	11
77	Coal	1	3	863	2
	Interval	8	0	871	2
78	Coal	1	3	874	5
	Interval, shale	26	0	892	5

Section of Bryson Mountain—Continued.

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
79	Coal and clay	2	11	901	4
	Interval	40	0	941	4
80	Coal	1	6	942	11
	Interval, sandstone, shale	110	0	1,052	11
81	Coal, Klondike (Bryson Mountain)	3	9	1,056	7
	Interval, shale	35	0	1,091	7
82	Coal, Poplar Lick, upper bench	1	6	1,093	1
	Interval	6	0	1,099	1
83	Coal, Poplar Lick, lower bench	1	8	1,100	9
	Interval	20	0	1,120	9
84	Coal	1	3	1,122	0
	Interval	190	0	1,312	0
85	Coal, Sandstone Parting	3	2	1,315	2
	Interval	70	0	1,385	2
85*a*	Cannel shale	1	8	1,386	11
	Interval	(a)		1,396	11
86	Coal	1	3	1,398	1
	Interval	(b)		1,422	1
87	Coal		8	1,422	9
	Interval	104	0	1,526	9
88	Coal	2	0	1,528	9
	Interval	30	0	1,558	9
89	Coal, Mingo	5	8	1,564	5

[a] 8 or 10 feet.

[b] 22 or 24 feet.

On Puncheon Camp Creek the following section was obtained:

Section up Puncheon Camp Creek.

No. on map.	Stratum.	Thickness.	
		Ft.	*In.*
	Sandstone	25	0
	Interval, hidden	30	0
	Sandstone	10	0
90	Coal	4	2
	Sandstone, laminated near bottom	50	0
91	Coal		10
	Sandstone, massive	65	0
	Shale	10	0
	Sandstone	10	0
	Shale	30	0
	Sandstone	5	0
	Shale	35	0
	Sandstone	8	0
	Shale, fissile	12	0
92	Coal, bloom		
	Interval, hidden	50	0
	Shale		(?)
99	Coal, Lower Hignite	5	5±
	Fireclay		(?)
	Interval, hidden	15	0
	Sandstone, very massive, cliff making	65	0
	Shale	40	0
	Interval, hidden	50	0
	Shale	30	0
95	Coal, bloom		(?)
	Shale	5	0
	Sandstone and shale	15	0
	Interval, hidden	30	0
	Sandstone, small cliff maker	20	0
	Interval	70	0
	Shale	10	0+
97	Coal, Klondike	5	4½
	Interval	90	0
98	Coal, bloom		(?)
	Interval	50	0
	Sandstone, massive cliff maker.	30	0
	Interval	120	0
	Shale and thin sandstone	20	0
	Limestone	2	0
	Interval	15	0
	Shale, black, bituminous	8	0+
101	Coal	(a)	
	Shale	3	0
	Coal	(b)	
	Shale, blue to green	15	0
	Sandstone	20	0
	Shale	0	0
	Interval	20	0
	Sandstone	5	0
102	Coal, thin		(?)
	Shale	10	0
	Interval	30	0
	Shale	20	0
	Interval to Mingo coal	50	0

[a] 6 to 8 inches.

[b] 8 to 12 inches.

This section does not show the Sandstone Parting coal, nor many of the smaller coals. It gives a little better idea of the details of the stratigraphy and what may be found on the slopes of the Log Mountains, or rather it shows how little is to be found, for it has been compiled by combining three sections, and only two of the coals whose thickness is given were seen in natural outcrop.

Mr. A. R. Crandall has prospected the coals on Slickrock Branch and Martin Branch of Stony Fork, and prepared the two following sections:

Section on Slickrock Branch of Stony Fork (Pl. XII).

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
	Interval from top	20	0	20	0
150	Cannel shale			20	0
	Interval	130	0	150	0
151	Coal, Hignite	3	9	153	9
	Interval	30	0	183	9
152	Coal		8	184	5
	Interval	20	0	204	5
153	Coal	2	10	207	3
	Interval	60	0	267	3
154	Coal	2	7	269	10
	Interval	70	0	339	10
155	Coal, Klondike	2	9	342	7
	Interval	105	0	447	7
156	Coal, Poplar Lick	3	8	451	3
	Interval	30	0	481	3
157	Coal	2	7	883	10
	Interval	35	0	918	10
158	Coal		6	919	4
	Interval	170	0	1,089	4
159	Coal, Sandstone Parting	3	5½	1,092	10
	Interval	110	0	1,102	10
160	Coal			1,102	10
	Interval	15	0	1,117	10
161	Coal			1,117	10
	Interval	60	0	1,177	10
162	Coal, thin			1,177	10
	Interval	30	0	1,207	10
163	Coal, position of Mingo (?)	1	8	1,209	6
	Interval	40	0	1,249	6
164	Coal		6	1,250	0
	Interval	120	0	1,370	0
165	Coal	1	6	1,371	6
	Interval to mouth of creek	190	2	1,561	6

Section on Martin Branch of Stony Fork (Pl. XII).

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
	Interval to top	40	0	40	0
173	Coal		10	40	10
	Interval	25	0	65	10
174	Coal	1	0	66	10
	Interval	55	0	121	10
175	Coal, Red Spring	5	4½	126	3
	Interval	20	0	146	3
176	Coal	1	6	147	9
	Interval	30	0	177	9
177	Coal	2	10	180	7
	Interval	50	0	230	7
178	Coal	3	2	233	9
	Interval	60	0	290	9
179	Coal	2	8	293	5
	Interval	70	0	363	5
180	Coal		6	363	11
	Interval, with sandstone	60	0	423	11
181	Coal	3	2	427	1
	Interval	60	0	487	1
182	Coal	3	1	490	2
	Interval	115	0	605	2
183	Coal, Upper Hignite	2	9	607	11
	Interval	25	0	632	11
184	Coal, Lower Hignite	4	5	637	4
	Interval	30	0	667	4
185	Coal		6	667	10
	Interval	110	0	777	0
186	Coal	1	0	778	10
	Interval	60	0	838	10
187	Coal	1	8	840	6
	Interval	20	0	860	6
188	Coal	1	2	861	8
	Interval	25	0	886	8
189	Coal	2	1	888	9
	Interval	30	0	918	9
190	Coal, Klondike (?)	4	9	923	6
	Interval	110	0	1,033	6
191	Coal, Klondike (A. R. C.), Poplar Lick (G. H. A.)	4	0	1,037	6
	Interval	30	0	1,067	6
192	Coal, Poplar Lick (A. R. C.)	2	3	1,069	9
	Interval	80	0	1,149	9

Section on Martin Branch of Stony Fork (Pl. XII)—Continued.

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
193	Coal	1	2	1,150	11
	Interval	100	0	1,250	11
194	Coal, Sandstone Parting	4	6	1,255	5
	Interval	70	0	1,325	5
	Cannel shale		1	1,325	6
195	Coal		6	1,326	0
	Interval	35	0	1,361	0
196	Coal			1,361	0
	Interval	100	0	1,461	0
197	Coal	1	0	1,462	0
	Interval	20	0	1,482	0
198	Coal	1	3	1,483	3
	Interval	30	0	1,513	3
199	Coal, Mingo (?)	2	5	1,515	8
	Space to mouth of branch	100	0	1,615	8

The coal thicknesses given in this section on Pl. XII exclude the partings.

The section at the Mingo No. 1 mine and Mingo Mountain, opposite the mouth of Puncheon Camp, or New Cabin Creek, is as follows:

Section at Mingo mines.

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
41	Coal, Klondike	3	6½	3	6
	Interval, hidden	24	0	27	6
	Clay shale	12	0	30	6
42	Coal, Poplar Lick	3	10	43	4
	Sandstone	15	0	58	4
	Interval	40	0	98	4
	Sandstone	10	0	108	4
	Shale	30	0	138	4
	Interval	110	0	248	4
	Shale	15	0	263	4
43	Coal, Sandstone Parting	5	2	268	6
	Clay shale	40	0	318	6
	Interval	50	0	358	6
	Sandstone	15	0	373	6
	Shale	5	0	378	6

Section at Mingo mines—Continued.

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
44	Coal, reported, with partings	([a])		382	6
	Interval, shale at Nicholson mine	155	0	537	6
45	Coal	1	10	539	4
	Sandstone	20	0	559	4
	Shale	1	0	560	4
46	Coal, Mingo (type locality)	5	5	565	9
	Interval	40	0	605	9
47	Coal	([b])		606	7
	Sandstone, Fork Ridge principal key rock	40	0	646	7
	Shale	20	0	666	7
	Interval	60	0	726	7
	Sandstone, lower cliff maker	40	0	766	7
	Shales	([c])		769	7
	Coal and shale	2	6	772	1
	Shale	10	0	782	1

[a] 3 to 4 feet. [b] 8 to 10 inches. [c] 6 inches to 2 feet.

Parts of the section at Yellow Creek mine will give some idea of what lies below the Fork Ridge sandstone.

Part of section at Yellow Creek mine.

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
	Fork Ridge sandstone (exposed)	20	0	20	0
	Interval	60	0	80	0
	Sandstone, lower cliff maker (exposed)	10	0	90	0
	Shale	80	0	170	0
31	Coal, bloom			170	0
	Clay shale	20	0	190	0
30	Coal	3	6	193	6
	Sandstone	4	0	197	6
	Shale	70	0	267	6
	Sandstone, shaly	15	0	283	6
	Shale	35	0	318	6
	Sandstone, shaly and laminated	10	0	328	6
	Shale	20	0	348	6
29	Coal, reported 15 inches	0	9	349	3
	Interval	10	0	359	3
	Sandstone in bed of Bennett Fork (section continued from bluff opposite Bennett Fork mine).				

Part of section at Yellow Creek mine—Continued.

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
	Interval	120	0	479	3
	Sandstone, massive, makes small cliffs	20	0	499	3
26	Coal, Upper Bennett Fork	4	4	503	7
	Clay	2	0	505	7
	Sandstone		8	506	3
	Clay shale, light drab	3	0	509	3
25	Coal		6	509	9
	Shale, thin beds of sandstone	6	0	515	9
24	Coal, 2 inches to		4	516	1
	Shale	3	0	519	1
	Sandstone, massive to bedded	20	0	539	1
23	Coal, Lower Bennett Fork	2	0	541	1

To show the variation in the interval between the two Bennett Forks coals, the following section, taken a little above the Bennett Fork mine, is instructive.

Section between two Bennett Fork coals near Bennett Fork mine.

No. on map.	Stratum.	Thickness.		No. on map.	Stratum.	Thickness.	
		Ft.	*in.*			*Ft.*	*in.*
	Sandstone, with shale partings.		0		Shale	1	0
	Clay shale	1	0		Sandstone	([a])	
28	Coal, Upper Bennett Fork	4	0		Shale	([b])	
	Clay shale	4	0	27	Coal, Lower Bennett Fork	3	6
	Sandstone	1	6				

[a] 6 inches to 1 foot.

[b] 0 to 6 inches.

Section near mouth of Bennett Fork.

No. on map.	Stratum.	Thickness.		No. on map.	Stratum.	Thickness.	
		Ft.	*in.*			*Ft.*	*in.*
	Sandstone, shaly, with shale partings	10	0		Shale	30	0
21	Coal, Upper Bennett Fork	3	2	19	Coal, bloom		0
	Interval, hidden	70	0		Shale	20	0
	Interval, mostly sandstone	70	0		Sandstone and interbedded shale, makes cliffs at mouth of valley	40	0
	Sandstone	30	0				

A section of the rocks believed to lie between this and the Cawood sandstone is exposed in the road from Middlesboro to Fern Lake.

Section on Fern Lake road.

No. on map.	Stratum.	Thickness. Ft.	Thickness. in.
	Sandstone, thought to be the same as at bottom of last section	10	0
	Shale	5	0
139	Coal	1	0
	Shale	70	0
138	Coal, thin		0
	Shale, pinkish, dark blue at bottom	30	0
	Sandstone, shaly	1	6
	Shale	1	0
	Sandstone, shaly	0	6
	Shale	1	0
137	Coal	0	0-2
	Shale	10	0
	Sandstone, shaly	5	0
	Shale	6	0
136	Coal	0	2
	Shale, drab to light brown	30	0
135	Coal	0	2
	Shale, dark drab	9	0
134	Coal, with partings	(a)	
	Sandstone, light brown, soft, shaly	13	0
133	Coal	1	0
	Fire clay, light drab	4	0
	Shale, light drab	3	0

[a] 4 to 9 inches.

CORRELATIONS.

The Mingo coal may be taken as a basal stratum along Bennett Fork, as it can be certainly traced along that stream from the Yellow Creek mine to where it passes under drainage at the Ralston No. 1 mine. With nearly, if not quite, equal certainty, the Fork Ridge sandstone, 40 feet below, was traced around Fork Ridge to the point where it passes under Stony Fork above the mouth of Coal Creek, though the Mingo coal is not definitely recognized on Stony Fork. Between 200 and 250 feet above the Mingo coal occurs the Sandstone Parting coal which can be traced around Fork Ridge. Above that 250 to 200 feet occur two workable coals within 30 to 50 feet of each other. It has been assumed that one of these—probably the lower one—is the Poplar Lick bed of Canada Ridge. On the Stony Fork side of Fork Ridge only one thick coal occurs at this horizon, which Mr. Crandall assumed to be the Klondike coal (Bryson Mountain coal of his report). On the north side of Stony Fork the Poplar Lick coal is everywhere workable, while about 115 feet above it is another coal locally workable. A comparison of the coal sections on Slickrock and Martin branches of Stony Fork with sections on Hignite, Coal Branch, and upper Stony Fork, and the intervals between the coals leads to the conclusion that the 4-foot coal upon the south side of Stony Fork corresponds with the Poplar Lick coal. Since the completion of the field work for this report Mr. David White, paleontologist of the Survey, visited the Bennett Fork field, and he calls attention to the fact that in that area the Klondike coal always contains pyritized marine fossil shells, while the Poplar Lick coal, as it is correlated on

Bennett Fork, carries only plant remains. With these data in mind examination made now would probably settle the question of the correlation of the 4-foot coal on the south side of Stony Fork, called by Mr. Crandall the Bryson Mountain coal. According to our interpretations, the coal worked at the Klondike mine on Bennett Fork corresponds with the coal 100 to 125 feet above the Poplar Lick coal in Canada Ridge, and with a 2- to 3-foot coal an equal distance above the "4-foot coal" ("Bryson Mountain coal," of Mr. Crandall) on the north side of Fork Ridge.

The correlation of the Turner coals is also in doubt. In the field they were thought to be the same as the Bennett Fork coals, and have generally been so considered. The data, however, seem to indicate that they are lower than the Bennett Fork coals. In the first place, a number of openings have been made on the lower of these coals in the eastern part of Mingo Mountain, and the sections obtained at these openings agree within a few inches, indicating persistence of detail; but they are quite different from the sections of the Lower Bennett Fork coal near the mouth of Bennett Fork. Second, the 200 feet of strata below the Bennett Fork coal at the mouth of Bennett Fork are largely sandstone (see p. 64). As exposed on the Fern Lake road, the 200 feet of strata below the Turner coals are almost exclusively shale. Near the mouth of Bennett Fork the strata have a strong dip to the west (15 feet in 100 feet), which carries the Bennett Fork coal from creek level, a little above the Bennett Fork mine, to 220 feet above the creek at a wagon mine near the mouth of the fork, or to about 1,400 feet above tide. The Turner coal at the Turner mine is about 1,430 feet above tide. On George Creek, which lies between the Turner mine and the mouth of Bennett Fork, were found several openings on two beds at 1,230 and 1,240 feet above tide (Nos. 16, 17) that were thought to correspond with the Upper and Lower Turner coals. If that correlation is correct, it would appear that the rise at the mouth of Bennett Fork continues to the east, so that the Bennett Fork coal would lie just about at the level of the gap at the head of the branch on which the Turner mine is located. East of the Turner mine the dip is to the east. The question could doubtless be settled in the field by actually tracing the sandstone.

COALS.

COALS OF HANCE FORMATION.

TURNER COALS.

Several openings have been made on the lower of two coals on Lane Branch of Yellow Creek in the eastern part of Mingo Mountain, and on the south side of the same mountain, facing Fern Lake. The Turner mine was opening up on a commercial scale when visited in 1903 and therefore the name has been applied to those coals. At the Turner mine the two coals are 20 feet apart. No section of the upper coal was seen, but it is supposed that the two coals of the following section, reported by McCreath and d'Invilliers, are the coals at the Turner mine and immediately above.

Sections of Jim Meyers (Turner?) coal, Mingo Mountain (McC. and d'I.).

	Ft.	in.	Ft.	in.
Sandstone roof.				
Upper Turner coal:				
Coal		1		
Slate, 1 inch to		4		
Coal	1	1		
Black clay, 0 inch to		2		
Coal		5		
Fire-clay(?) shale		11		
Coal	1	2		
Clay shale and sandstone		8		
Coal		5		
Clay		9		
Sandstone		2		
Shale	1	3		
Cannel coal, impure		1½		
Coal	1	5		
			8	11½
Interval, mostly sandstone			20	0
Lower Turner coal:				
Coal	1	8		
Slate		2½		
Coal	2	4		
			4	2½

Messrs. McCreath and d'Invilliers describe the coal at this point as having a high southeasterly dip and slickensides and polished surfaces. The possibility of error in the measurements is admitted. At an opening in the lower coal on the east side of Lane Branch measurements gave from 18 to 25 inches of coal in the upper bench, 26 inches of coal in the lower bench, with from 2 inches to 1 foot of clay between (9). This agrees so closely with the above section that it leaves little doubt that it is the same coal. At most of the openings where this coal was measured the partings were over a foot thick. On the west side of Turner Branch opposite the opening last mentioned the upper bench measures 30 inches, the lower 26, and the clay partings 16. A sandstone comes 1 foot below the coal. At the Turner mine the upper bench measured 25 inches, the lower 24 inches, with a 20-inch parting between (13). There is a clay shale roof of 5 feet, with sandstone above that. On Little Yellow Creek above Fern Lake this lower coal shows 2 benches as in the openings just mentioned, the upper being 28 inches, the lower 23, with 8 feet plus of shale roof, and light-drab fire clay below (7). Above the shale roof there is sandy shale or shaly sandstone for 12 feet or more. Taken as a whole this lower coal has a roof of from 1 to 5 feet of shale with sandstone above. The thickness of the upper bench ranges from 18 to 30 inches, and averages as far as seen about 2 feet; that of the lower bench ranges from 22 to 28 inches, and averages about 26 inches. The parting is from 2 to 20 inches thick and averages about 1 foot. Beneath there is from 1 to 4 feet or more of drab fire clay underlain by sandstone.

COALS OF MINGO FORMATION.

BENNETT FORK COALS.

These coals are so named because the uppermost of them is extensively mined on Bennett Fork at the Winona mine. They are here reported 16 feet apart; a short distance west they were exposed in old openings only 8 feet apart (see section, Pl. XI). At the Bennett Fork mine the upper coal ranges from 3 feet 6 inches to 6 feet in thickness, with an average of 4 feet (23). The section shows an upper bench of 6 inches, then a parting of 6 inches underlain by one-half inch to 1½ inches of bone coal, which forms the top of the middle bench 12 inches thick. Below that is a 2-inch parting; then comes the main bench 20 inches thick, with another 2-inch parting separating 3 inches of coal at the bottom. The roof is sandstone. Mining is in the upper 2-inch clay of the section. Where the coal shows its greatest thickness all the benches have thickened up, the coal gaining more than the clay, the upper bench at such times thickening from 6 inches to 1 foot. A thin streak of sulphur runs 1 inch from the bottom of the 1-foot bench. The top and bottom benches are the purest. The roof consists of 15 + feet of sandstone separated from the coal by from 1 foot to 8 inches of shale. The lower coal at this point is reported to be 4 feet thick with a very hard parting 1 foot thick. According to the section by McCreath and d'Invilliers, this parting is more than half sandstone.

The various sections of the upper coal show considerable regularity; thus at the north side of Bennett Fork (20) the coal has a total thickness of 44½ inches in four benches—6, 9, 13, and from 6 to 9 inches—with partings of 4, 2½, and from one-half to 1 inch. This section agrees closely with the section at the Bennett Fork mine. The roof here is a shaly sandstone. The section on the upper coal at the old openings mentioned (28) shows the upper bench to have 4 inches of coal, then 10 inches of clay, with 1½ inches of coal 3 inches from the bottom. The main body of coal is separated by two partings—a 2-inch parting 20½ inches from the bottom and one-half inch parting 3 inches from the bottom. The section reported by McCreath and d'Invilliers at the old Tudor mine showed the upper bench of 5 inches divided by a one-fourth inch parting 3 inches from the top; then came 9 inches of shale, then 32 inches of coal, with a 1-inch parting 13 inches from the top. As seen from these figures the upper bench is from 4 to 6 inches thick, the first parting from the top from 5 to 9 inches, sometimes with a streak of coal or a little bone at its base. The second bench averages about 1 foot thick. Then comes a 1- to 2½-inch parting, then a bench from 13 to 10 inches thick, a one-half to 2-inch parting, and a 3- to 9-inch bottom bench of coal. The underlying coal at the Tudor opening, as reported by McCreath and d'Invilliers, shows two benches, the upper of which is 10 inches and the lower 28 inches, with a 2-inch bone at the bottom. The parting between these two benches consists of 2 inches of bone, 5 inches of shale, and 7 inches of sandstone. At the old opening on the lower coal (27) the coal shows 40 inches, not including a 2-inch parting 6 inches from the bottom.

MINGO COAL.

Up to 1903 this bed has supplied most of the output of Bennett Fork. There are commercial openings on this bed at the Nicholson, Mingo Nos. 1 and 2, Fork Ridge, Reliance, Bryson, and Ralston No. 1 mines. It yields from 4 to 5 feet of workable coal in a total thickness of 5 to 10 feet. It shows one persistent parting a little below the center, which varies from 2 inches to 4 feet or more. In most of the working mines this parting runs from 6 to 8 inches. Near the bottom of the coal is often another parting that varies from 0 to 6 inches, though it is usually less than 2 inches. The main partings tend to increase in size so that at the upper and lower ends of the district in which this coal is being worked the coal loses it workability. A series of sections up Bennett Fork will show the variations in this bed.

(32) *Section of Mingo coal at Yellow Creek mine.*

Clay shale roof, 12 feet.	Ft.	in.		Ft.	in.
Coal	2	10	to	3	2
Clay	1	10	to	1	10
Coal		4	to		4
Clay		3	to		3
Coal					1
Clay	2	0	to	2	0
Coal	1	10	to	2	0
Clay		3	to		3
Coal		6	to		6
Total	9	10	to	10	5

(36) *Section of Mingo coal at Nicholson mine.*

Sandstone, 6+ feet.

Clay shale roof, 5 feet.	Ft.	in.
Coal	1	1
Clay		1
Coal		7½
Clay		[a] 0¼
Coal		1½
Clay		[b] 0½
Coal		2½
Clay		3
Coal		4
Clay	1	4
Coal	1	8
Total	5	9¼

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[a] ⅛ to ¼ inch.

[b] to ⅛ inch.

In some new entries being driven here the coal was badly cut up by partings, as shown above. These partings are quite variable and tend in places to run out. In some of the entries the partings are much reduced in number, as shown by the following section taken not far from the preceding:

(36a) *Section of Mingo coal at Nicholson mine.*

	Ft.	in.
Coal	2	10
Clay		[a]0½
Coal		3
Clay	1	3
Coal	1	8
Total	6	0½

Two sections at the Mingo No. 1 mine show the average section, and a measurement in the lower entry shows the variableness in the upper bench. In the first case the roof consists of 1 foot of shale under shaly sandstone, with solid sandstone above. In the second case the sandstone comes down to the coal.

(46) *Section (average) of Mingo coal at Mingo No. 1 mine (type locality).*

	Ft.	in.
Shale roof.		
Coal	2	8
Clay		[b]8
Coal	1	6
Clay		[c]1
Coal		6
Total	5	5

(46a) *Section of Mingo coal at Mingo No. 1 mine.*

	Ft.	in.
Sandstone roof.		
Coal	3	5½
Clay		8
Coal	1	6
Clay		6
Coal		6
Total	6	7½

(59) *Section of Mingo coal at Fork Ridge mine.*

	Ft.	in.
Clay shale roof, 20+ feet.		
Coal	2	1
Clay		10
Coal	1	5
Clay		[d]2
Coal		[e]7
Total	5	1

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[a] 6 inches to ½ inch.

[b] 2 to 10 inches.

[c] ½ to 1 inch.

[d] 0 to 6 inches; average 2 inches.

[e] 7 inches to 1 foot.

From Puncheon Camp to Sugan Branch this coal runs quite regularly, as may be judged by comparing the section last given with the following section, measured at the Bryson mine. The roof here consists of 1 foot of clay shale under 5 + feet of firm sandy shale.

(57) *Section of Mingo coal at Bryson mine.*

	Ft.	In.
Shale roof.		
Coal	2	1
Clay		8
Coal	1	5½
Clay		2½
Coal		5½
Total	4	10½

The following section of the Mingo coal at the mouth of Sugan Branch is given by McCreath and d'Invilliers.

Section of Mingo coal at Sugan Branch.

	Ft.	In.
Shale roof.		
Coal	2	8
Coaly shale and "slate"		3
Coal	1	10
Shale streaked with coal		5
Coal somewhat bony	1	8
Total	5	9

This section shows nearly 1 foot greater thickness than the preceding. At the Bryson mine an 8-inch parting thickens on going into the mountain. This thickening is still more pronounced at the Ralston No. 1 mine (49), where the parting becomes 4 feet thick. There is here from 2 feet 6 inches to 3 feet of coal above the parting and from 2 feet 4 inches to 2 feet 6 inches of coal below. A considerable area was worked out here in the hope that the parting would become thinner. In one part of the mine the parting thinned down to 7 inches and increased beyond.

On Stony Fork the position of this coal is indicated by that of the Fork Ridge sandstone. It was thought that this sandstone was traced with certainty from Bennett Fork around the end of Fork Ridge and all around Stony Fork where it is above drainage, and yet nowhere was a coal found 40 feet above its top that resembled in thickness or partings the Mingo coal of Bennett Fork. Evidently either a mistake was made in tracing the sandstone or the Mingo coal has become thin and unworkable in that area. In the assumed position of the Mingo coal is found a coal from 15 to 20 inches thick, with a thin coal 20 to 30 feet above it and a somewhat thicker coal 30 to 40 feet below. The position of the three coals corresponds closely with that of the Mingo and first coal above and below it on Bennett Fork.

COALS OF CATRON FORMATION.

Between the Lower Hignite coal and the Klondike coal no coals of importance appear, as is shown by Mr. Richardson's section on Bryson Mountain.

POPLAR LICK COAL.

At the Mingo mines the Poplar Lick coal lies 36 feet below the Klondike coal. At the Nicholson mine these coals were 40 feet (bar.) apart. In Slickrock and Martin branches of Stony Fork, Mr. Crandall has assumed that the Klondike and Poplar Lick coals were represented by two coals 30 feet apart, of which only the upper is workable. This agrees well with what was found on Bennett Fork, but does not agree with what occurs on the north side of Stony Fork. As already stated, Poplar Lick coal in Canada Ridge is a persistently workable coal and has been extensively tested and mapped in that area. As a rule in that region no coal has been found in the first 75 to 100 feet above the Poplar Lick coal. The first coal above lies from 75 to 125 feet above, and though locally workable is not so usually. It would therefore seem more probable that the 4-foot coal, at an elevation of 820 feet above the mouth of Slickrock Branch and of 563 feet above the mouth of Martin Branch, is the Poplar Lick coal, and it will be so considered here. On this basis the Poplar Lick coal may be considered as a 4-foot coal along Stony Fork, and generally workable; and as from 3 to 4 feet thick on Bennett Fork, and only questionably workable at most places on account of its partings. It is being mined at Mingo No. 1 mine. The roof is generally shale. At the Nicholson mine (38) a partial facing showed it to occur in two benches, apparently about 18 inches thick each and 18 inches apart. At the Mingo mine (42) it shows about 46 inches of coal, with a 2-inch parting in the middle. The floor here is sandstone and the roof shale. A section reported on Bennett Fork by Mr. Crandall showed 54 inches of coal with two main benches, the upper one 17 inches thick and the lower one 26¾ inches thick, with several thin benches and partings between (111). On the right-hand fork of Slickrock Branch of Stony Fork, Mr. Crandall reports this coal to be 42 inches thick, with a 1-inch shale parting 7 inches from the top (167). On Martin Branch of Stony Fork he reports it to show 48 inches of solid coal (191). A section of this coal by Messrs. McCreath and d'Invilliers on Slickrock Branch of Stony Fork made this coal 3 feet 7 inches thick in four benches, of which the uppermost is 1½ inches, the next 4½ inches, then 1½ inches, and the lower bench, which is somewhat bony, is 2 feet thick; 2½ inches of the uppermost parting is coal and shale; the lower part of the parting has a thickness of 5½ inches; the two partings below are 1½ inches and 2 inches thick. On Camp Branch of Stony Fork Mr. Crandall reports this coal as only 21 inches thick with two shale partings. Analyses of this coal in the Clear Fork field indicate a good quality of coal, as shown in the discussion of that district.

KLONDIKE COAL.

This coal is named from the Klondike, or Ralston No. 3, mine where alone it was being worked in 1902. Since then commercial openings have been made upon it at Mingo and Nicholson mines, and in 1894 an opening is reported as having this coal makes a somewhat better showing, as reported by Mr. Crandall. It has there two partings, the upper one, 20 inches from the top, is 6 inches thick, and the lower one, 10½ inches from the bottom (203), is 5½ inches thick. The sections that have been given show this coal to have a total thickness not including the extremes of from 4 to 6 feet, of which from 3 feet 6 inches to 6 feet consist of workable coal, averaging a little over 4 feet on Bennett Fork and less than 4 feet on Stony Fork.

Analyses of Klondike coal.

Constituent.	A.	B.	C.	D.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	3.492	1.308	3.00	1.44
Volatile combustible matter	35.683	38.042	32.05	32.56
Fixed carbon	50.373	49.671	59.83	53.34
Ash	9.530	8.545	4.41	12.66
Sulphur	.923	2.434	.76	1.454

A. From opening (55) on Sugan Branch of Bennett Fork; analysis by McCreath; samples collected by McCreath and d'Invilliers.

B. Shade Branch of Bennett Fork; analysis by McCreath; sample collected by McCreath and d'Invilliers.

C. Lick Hollow, Hurricane Branch, one-fourth mile above the mouth of Grays Branch, Clear Fork drainage (122); analysis by Robert Peter; sample collected by A. R. Crandall.

D. Shade Branch of Bennett Fork; analysis by Robert Peter; sample collected by R. C. B. Thruston.

The sample obtained on Shade Branch by Mr. Thruston was probably from the facing sampled by Mr. McCreath. Mr. McCreath reports that his sample included the two benches of bony coal, 4½ and 2 inches thick, which did not occur at the Hurricane Branch locality. Practical coking tests of this coal are said to have been made at the Mingo ovens, and though the coal was not washed the result was reported to be entirely satisfactory. Notwithstanding the thick parting that develops at the Klondike mine, this coal seems to be usually rather free from partings and to present a thickness of coal that will make it an important factor in the future development of the Bennett Fork field. The bottom 2 or 3 inches of the coal tends to be soft and often worthless, as at the Nicholson and Mingo mines, and at the opening (55) on Sugan Branch. The lowest 3 inches of the 1½-foot bench of coal on Shade Branch is reported to be soft; the same bench is reported to carry sulphur in irregular streaks and concretions at about 6 inches from the floor. This probably accounts for the large percentage of sulphur shown in the coal from this opening.

COALS OF HIGNITE FORMATION.

This formation carries three workable coals in the Bennett Fork district—the Red Spring coal at the top, the Lower Hignite coal at the bottom, and at least one intermediate coal of workable thickness.

LOWER HIGNITE COAL.

As far as recognized the Upper Hignite coal is not workable in this area, nor was a workable thickness at its horizon seen at any point in the area. The Lower

Hignite coal, on the contrary, has an average thickness of almost 5 feet, ranging from 41 inches to 69½ inches. The first commercial opening upon this bed was made on New Cabin Creek (99) in 1903 by the Fork Ridge Coal and Coke Company. The section at this new opening shows a total thickness of 5 feet 4 inches, of which 5 feet 1 inch are of workable coal. There are two partings—the upper, 2 inches thick, is 41 inches below the roof; the other, 1½ inches thick, is 8 inches above the floor. The roof here is shale. This coal was found at Little Coal Gap by Mr. Crandall (119), who reports that it is 69½ inches thick, an upper bench of 16 inches being separated from the lower portion by a parting of 14 inches of clay and coal; the lower 37 inches of coal has a 2½-inch parting 14 inches from the top. Several sections have been obtained by Mr. Crandall on Puncheon Camp Creek. One below the right-hand fork of Puncheon Camp Creek (115) shows 65 inches of coal without a parting; another (117) gives 60½ inches with only one parting from 1 to 3 inches thick 6½ inches from the bottom. The section on the right-hand fork of Puncheon Camp Creek (116) showed 51 inches of workable coal with a one-half inch parting 5 inches from the bottom; 3 inches of coal appears 8 to 11 inches lower. The roof in all of these cases is shale. A series of sections across Log Mountains to the southwest shows this coal to maintain an excellent thickness. One of these sections (120) is given on Pl. X, which shows 58½ inches of coal, plus 7½ inches of partings. On Slickrock Branch of Stony Fork Mr. Crandall reports this coal to be 61 inches thick (168). There is an upper bench of 37 inches, then 3 lower benches of 5, 1, and 8 inches, with partings of 5, 1½, and 3½ inches, respectively. On Martin Branch of Stony Fork Mr. Crandall reports this coal (184) to show 42½ inches of solid coal overlain by 11½ inches of mixed coal and clay. The roof is shale. On Camp Branch of Stony Fork Mr. Crandall reports this coal to be 41 inches thick, with shaly sandstone roof (205). From these sections it would appear that the coal on Stony Fork is a little thinner than farther south, the minable coal there averaging nearer 40 inches. On the whole there is little agreement in detail, many of the sections showing clean coal the full thickness, while others are much cut up by partings. While the coal thus described has been considered to be at one horizon and to be the equivalent of the Lower Hignite coal, no satisfactory criteria were found for distinguishing the horizon of the lower coal from that of the upper, unless the position of the massive sandstone found all through this district 20 feet or so below the coal may be considered such. Aside from this evidence, the assumption that this coal is at the lower rather than at the higher horizon is arbitrary and is based on conclusions reached by Mr. Crandall and others. No analyses of this coal in this area were obtained. Analyses in the Clear Creek district show an excellent coal. The Lower Hignite can hardly be considered a workable coal in Mingo Mountain, as it occurs at an elevation of about 2,600 feet, and, as shown by the map, underlies only the narrow crest between Coal Gap and Wilson Gap, with a few acres to the east of Wilson Gap. In Bryson Peak two barometric measurements gave this coal an elevation of about 2,530 feet, and, as shown by the map, that allows it a good acreage, measuring to a line below the crest, which is as far as we have data for. In Fork Ridge much the same conditions exist as in Mingo Mountain. The coal is too near the crest to be considered workable.

RED SPRING COAL.

As shown on Pl. X, p. 56, two sections of the Red Spring coal were obtained. Mr. Richardson's section of Bryson Mountain (64) gives this coal a thickness of 6 feet 7 inches, including two partings, the upper parting being 10 inches thick and 45 inches from the top, the lower parting 8 inches thick and 3 inches from the bottom. Another section of this coal on Martin Branch of Stony Fork (176), reported by Mr. Crandall, showed 62½ inches of coal, including three partings—the upper one 1 inch thick 10 inches from the top, the lowest one 1 inch thick and 2 inches from the bottom, and a ½-inch parting 1 inch higher. The roof here is sandstone. In the Bennett Fork section the roof was shale for 10 inches, then sandstone above. Of the other coals between the Red Spring coal and the Lower Hignite coal, only one need be considered, and that is only doubtfully workable. A section of this coal obtained by Mr. Richardson (67) showed 38 inches of coal in 5 benches, which, beginning at the top, had thicknesses of 4, 4, 2, 9, and 19 inches; at the top was 4 inches of coal and clay; below were partings of 4, 6, 2, and 3 inches. The 9 and 19 inches of coal at the bottom separated by 3 inches of clay might be considered workable if it occurred near the foot of the mountain rather than near the top. Another section on Puncheon Camp Creek (90) shows this coal to have 4 benches 6, 3½, 2, and 25 inches in thickness, separated by partings of 3, 8, and 2½ inches. The roof is sandstone. This coal lies 240 feet above the Lower Hignite coal.

COAL OF BRYSON FORMATION.

The Bryson formation forms the crest of Bryson Peak and the western end of Fork Ridge. Two of the coals found in this formation on Bryson Mountain are given on Pl. X. Mr. Richardson's section in Bryson Mountain shows three coals, viz, coal (61) 1 foot 3 inches, coal (62) 6 feet 8 inches, and coal (63) 3 feet 3 inches. The 39-inch coal is of workable thickness, but can hardly be considered workable on account of the very limited area it necessarily underlies. Coal (62) given as 6 feet 8 inches thick is really divided into a large number of benches, no one of which is of workable thickness. These benches measure as follows: 20 inches, 1 inch, 2 inches, 18 inches, 6 inches of clay and coal, 2 inches, 1 inch, and 2 inches. Between these benches are clay partings of 3, 2, 12, 7, 2, and 2 inches.

SUMMARY.

In the preparation of the following summaries the attempt has been made to ascertain with considerable accuracy the area underlain by the principal coals, and the outcrops have been traced for that purpose. Unless the coal has been seen at a large number of points fairly well distributed over the district, and gives evidence of being workable at all places visited, as, for example, the Harlan coal in the eastern districts, an estimate has been made, based upon the data at hand, of the portion of the coal area that may be considered as workable. In a few cases, as the Harlan coal just mentioned, the area of workable coal may be practically equal to the area underlain by the seam. In the eastern districts it is probable that the total amount of workable coal greatly exceeds the estimates, for the reason that information concerning the coal is less complete than it is of the region of the two districts of the Log Mountains. On the other hand, the amount of coal which may practically be considered as workable—that is, which in the future, if present mining conditions continue, will actually be mined—will probably be much less or at least no more than the amount given for each district. It must be admitted that in many cases the estimate of the proportion of a given bed that will yield workable coal is so largely a matter of personal judgment that those figures can not be considered as in any sense authentic for any given coal. Where, however, several coals are grouped together, it is more than possible that the error made with one coal may be offset by an opposite error with some other coal, leaving the total result fairly accurate. With the small amount of data at present at hand about most of the coals of the eastern area, these figures must be considered as only tentative, to be revised when a careful exploitation by drilling and facing shall have yielded a large amount of additional information.

Summary of coals of Bennett Fork district.

Number of coal beds found		50+
Total thickness of coals	feet..	95±
Number of coal beds of workable thickness (2 feet+)		13
Number of coals worked at present		7
Average thickness of principal workable coals	feet..	5
Total thickness of workable coal beds	do...	40+
Total thickness of coal in workable coal beds	do...	30+
Greatest thickness of single coal bed measured	do...	$9\frac{3}{8}$
Greatest thickness of coal in single bed measured	do...	$5\frac{5}{8}$

Summary of coals in Bennett Fork district.

	Hignite.	Red Spring.	Klondike.	Poplar Lick.	Sandstone Parting.	Mingo.	Bennett Fork and Turner.
Approximate elevation, above tide..........feet..	2,600	3,000	2,350	2,300	1,950	1,700	1,400
Thickness:							
Greatest.........do....	$5\frac{3}{4}$	$6\frac{7}{12}$	$9\frac{1}{2}$	$4\frac{1}{2}$	$5\frac{3}{8}$	$9\frac{3}{8}$	6
Average.........do....	5	$5\frac{7}{8}$	$5\frac{1}{12}$	4	$4\frac{1}{2}$	$6\frac{1}{2}$	4
Least ....do....	$3\frac{5}{12}$	$5\frac{5}{24}$	4	$3\frac{1}{2}$	$3\frac{1}{3}$	$4\frac{7}{8}$	....
Average thickness of workable coal ....feet..	$4\frac{1}{2}$	5+	4	$3\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{1}{2}$	$3\frac{1}{2}$
Number of measurements...	9	2	13	5	8	8	10
Area of seam........acres..	1,000	200	1,500	3,000	2,000	8,000	5,000
Available coal per acre, tons......................	6,500	6,000	5,000	4,000	4,000	6,000	4,000
Coal available in district, tons......................	6,500,000	1,000,000+	7,500,000	8,000,000	8,000,000	6,000,000	20,000,000

drainage a short distance above. At the Bennett Fork mine (23) the main entry, driven straight into the hill, is about on the strike, though rising slightly. Haulage is difficult on the west side of the mine.

On the north side of Bennett Fork opposite the Bennett Fork mine the top of the Fork Ridge sandstone, which there caps the top of the mountain, is 1,680 feet (bar.) above tide. As it has practically the same elevation at the mouth of Puncheon Camp Branch of Bennett Fork, a line from Rock Branch to Puncheon Camp Branch appears to run on the general strike. As a matter of fact the westward dip from the mouth of the stream continues a little above Rock Branch. From the transverse synclinal axis probably there is a slight rise upstream to the mouth of Puncheon Camp Branch. Above that the rise is more marked, probably in part due to the southward deflection of the headwaters of Bennett Fork. At the Yellow Creek mine the top of the Fork Ridge sandstone is found at 1,700 feet (bar.) or 320 feet above the creek. The Mingo coal is opened a few feet higher and just over the commissary. The Sandstone Parting coal being mined here is by barometer about 2,060 feet above tide. The Poplar Lick and Klondike coals should be found in the top of the ridge here, underlying very small areas, at elevations of about 2,240 and 2,280 feet, respectively. At the Nicholson mines two openings on the Mingo coal are at elevations (bar.) of 1,710 and 1,730 feet above tide, while the Sandstone Parting, Poplar Lick, and Klondike coals gave a trifle lower reading than at the Yellow Creek mine. The Klondike coal is near the top of the ridge, but has enough body to lead to its being mined at this point.

Around the mouth of Puncheon Camp Branch and up Bennett Fork the structure is well shown by the following exact elevations above tide on the Mingo coal at the mines named: Fork Ridge mine, 1,693 feet; Reliance mine, 1,724 feet; Mingo No. 1 mine, 1,739 feet; Mingo No. 2 mine, 1,771 feet; Bryson mine, 1,796 feet; Ralston No. 1 mine, 1,814 feet. At the Mingo No. 1 mine the Mingo coal is 260 feet above Bennett Fork; at Ralston No. 1 mine it barely drains into the creek, the rise of the creek having brought its channel up to the level of the coal. At the Mingo No. 1 mine the spaces to the upper coals have been very accurately measured. From the Mingo coal to the Sandstone Parting coal is 285 feet; from the latter to the Poplar Lick coal is 230 feet, with the Klondike coal 36 feet higher. These elevations added to the exact elevations given above. with due allowance for dip, should give about the position of the upper coals. The Lower Hignite coal may occur near the crest of Mingo Mountain near Wilson Gap, but not in minable quantity. It is probable that along a northwest-southeast line through Mingo Mountain, from Bennett Fork, at right angles to the general strike, the rise will be more or less regular until the crest is passed, when it will become much sharper. What was taken to be the Fork Ridge sandstone was noted on the south slope of Mingo Mountain at an elevation (bar.) of 2,040 feet, 360 feet below the saddle at Wilson Gap and 300 feet above its elevation at Mingo. At one point it dips N. 45° (?) W. at an angle of 12°.

Around the east end of Fork Ridge and along the north or Stony Fork side the top of the Fork Ridge sandstone is found to have the following barometric elevations above tide: On the end of the nose, 1,650 feet above tide; Slickrock Branch, 1,560 feet; Martin Branch, 1,670 feet; Camp Branch, opposite the mouth of Coal Branch, 1,740 feet; Stony Fork, about 1,760 feet. On Slickrock Branch the top of this sandstone is 300 feet (bar.) above the mouth. About 300 feet higher (or at 1,855 feet) is the Sandstone Parting coal, as reported by Crandall and by McCreath and d'Invilliers, the interval agreeing with that found on Bennett Fork. On Martin Branch the top of the Fork Ridge sandstone is about 140 feet above the mouth of the branch. The Sandstone Parting coal with a characteristic section is reported by Mr. Crandall to occur 350 feet above the mouth. This makes the interval between it and the Fork Ridge sandstone 100 feet less than the normal. It is not possible at a distance to say where the discrepancy lies. The Poplar Lick coal lies from 200 to 250 feet above the the Sandstone Parting coal, the Lower Hignite from 300 to 360 above that, and the Red Spring coal, when present, 500 feet higher. The Red Spring coal is hardly workable in Fork Ridge on account of its nearness to the crest. It occurs only in the western part of the ridge.

STONY FORK-CLEAR CREEK DISTRICT.

GEOGRAPHY.

The area treated under this heading consists of the portion of the Log Mountains field between Big Clear Creek on the north and Camp Creek, Stony Fork, and Yellow Creek on the south. In order to reduce the map to the size of a page[a] plate, the eastern boundary is an arbitrary line up Fourmile Run, across the head of Cannon Creek, down Fuson Branch of Little Clear Creek, and north to Pine Mountain. The topography around Middlesboro has already been described (pp. 23–28). In the rest of the territory it is of the same type as in the Bennett Fork district, the streams having a fairly uniform descent from head to mouth. Switch backs would be required to enable railroads to reach the coal on the smaller streams.

The Cumberland River and Tennessee Railroad was built up Clear Creek to Chenoa in 1893. A cannel coal was extensively mined at Chenoa until 1899, but the entries were driven down the dip, which was so steep as to finally render mining unprofitable. Had the railroad been run up Little Clear Creek the coal could have been entered at the lowest part of the bed with more satisfactory results. Three mines began operations in the Stony Fork basin in 1903–4.

STRATIGRAPHY.

It is probable that a higher point stratigraphically is reached in the mountains at the heads of Hignite and Coal creeks than anywhere else in the area studied. Like the last district, this one has been quite thoroughly tested, though little actual mining has yet been done. A series of columnar sections is presented on Pl. XII.

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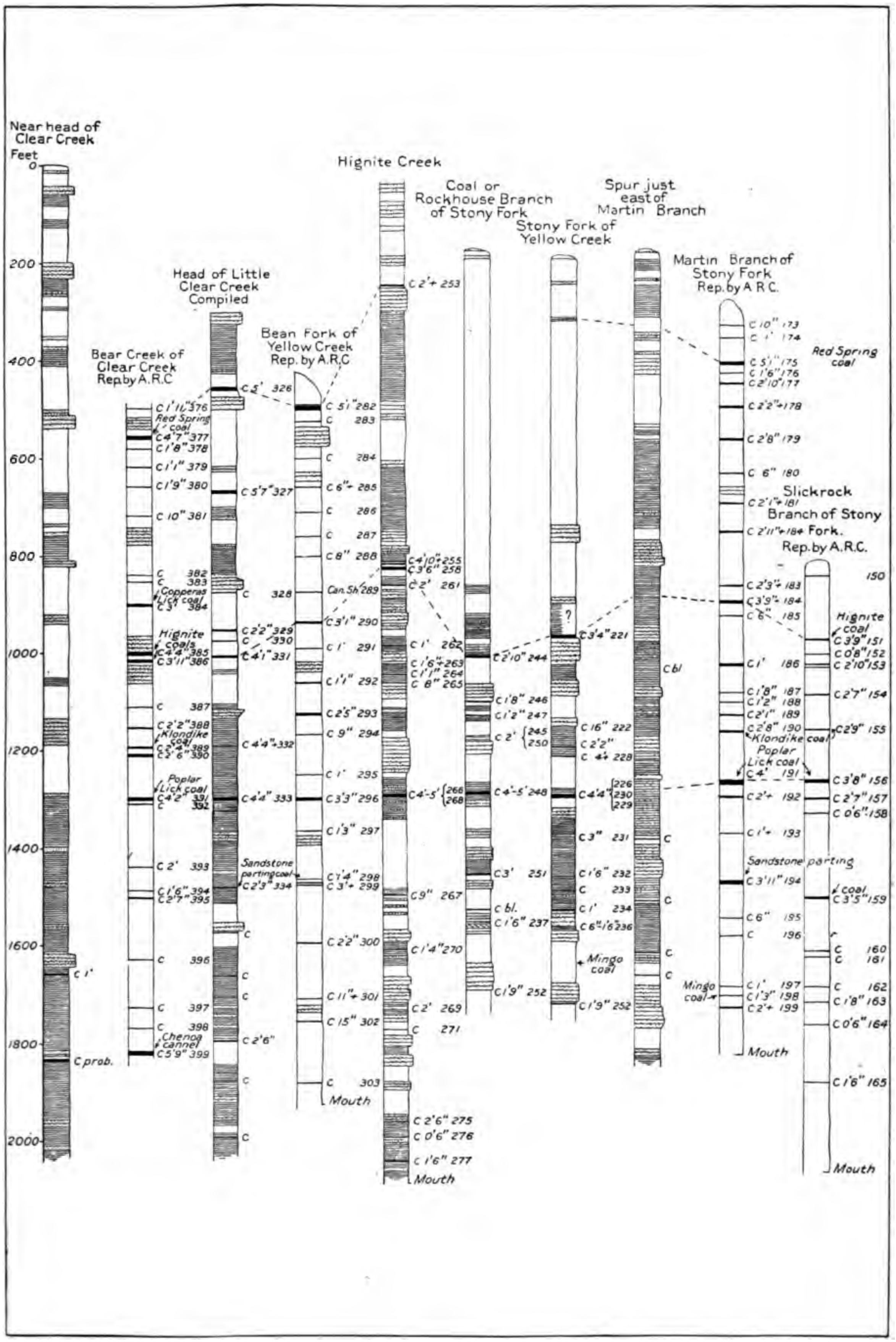
[a] The page maps have been combined into Pl. XL, in pocket.


Near head of Clear Creek
Feet
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Bear Creek of Clear Creek Rep. by A.R.C.
Head of Little Clear Creek Compiled
Bean Fork of Yellow Creek Rep. by A.R.C.
Hignite Creek
Coal or Rockhouse Branch of Stony Fork
Stony Fork of Yellow Creek
Spur just east of Martin Branch
Martin Branch of Stony Fork Rep. by A.R.C.
Slickrock Branch of Stony Fork. Rep. by A.R.C.
Red Spring coal
Copperas Lick coal
Hignite coals
Klondike coal
Poplar Lick coal
Chenoa cannel
Can. Sh.
Sandstone parting coal
Sandstone parting
Mingo coal
Hignite coal
C prob.
Mouth

COLUMNAR SECTIONS, STONY FORK-CLEAR CREEK DISTRICT.

Scale: 1 inch=300 feet.

The first section needs no description, the lowest coal bloom is thought to be the Chenoa cannel coal. The other sections may be described to give the details of the coals.

Section on Bear Creek near head of Clear Creek (A. R. Crandall).

No. on map.	Stratum.	Thickness.		Total thickness of section.	
		Ft.	*in.*	*Ft.*	*in.*
	Interval from crest of mountain	20	0	20	0
376	Coal	1	11	21	11
	Interval, sandstone and shale	60	0	81	11
377	Coal, Red Spring	4	7	86	6
	Interval, shale	20	0	106	6
378	Coal	1	8	108	2
	Interval, shale	40	0	148	2
379	Coal	1	1	149	3
	Interval, shale and sandstone	40	0	189	3
380	Coal	1	9	191	0
	Interval, shale and sandstone	60	0	251	0
381	Coal		10	251	10
	Interval, sandstone and covered	120	0	371	10
382	Coal, thin				
	Interval	15	0	386	10
383	Coal, thin				
	Interval	45	0	431	10
384	Coal, Copperas Lick	3	0	434	10
	Interval, some sandstone	100	0	534	10
385	Coal, Upper Hignite	4	4	539	2
	Interval, shale	20	0	559	2
386	Coal, Lower Hignite	3	11	563	1
	Interval, shaly, sandstone near top	95	0	658	1
387	Coal, thin				
	Interval	40	0	698	1
388	Coal	2	2	700	3
	Interval	40	0	740	3
389	Coal	2	4	742	7
	Interval	20	0	762	7
390	Coal, Klondike(?)	2	6	765	1
	Interval	90	0	855	1
391	Coal, Poplar Lick	4	2	859	3
	Interval, shale over coal	10	0	869	0
392	Coal, cannel coal				
	Interval	125	0	994	0
393	Coal	2	0	996	0
	Interval, shale	50	0	1,046	0

Section on Bear Creek near head of Clear Creek (A. R. Crandall)—Continued.

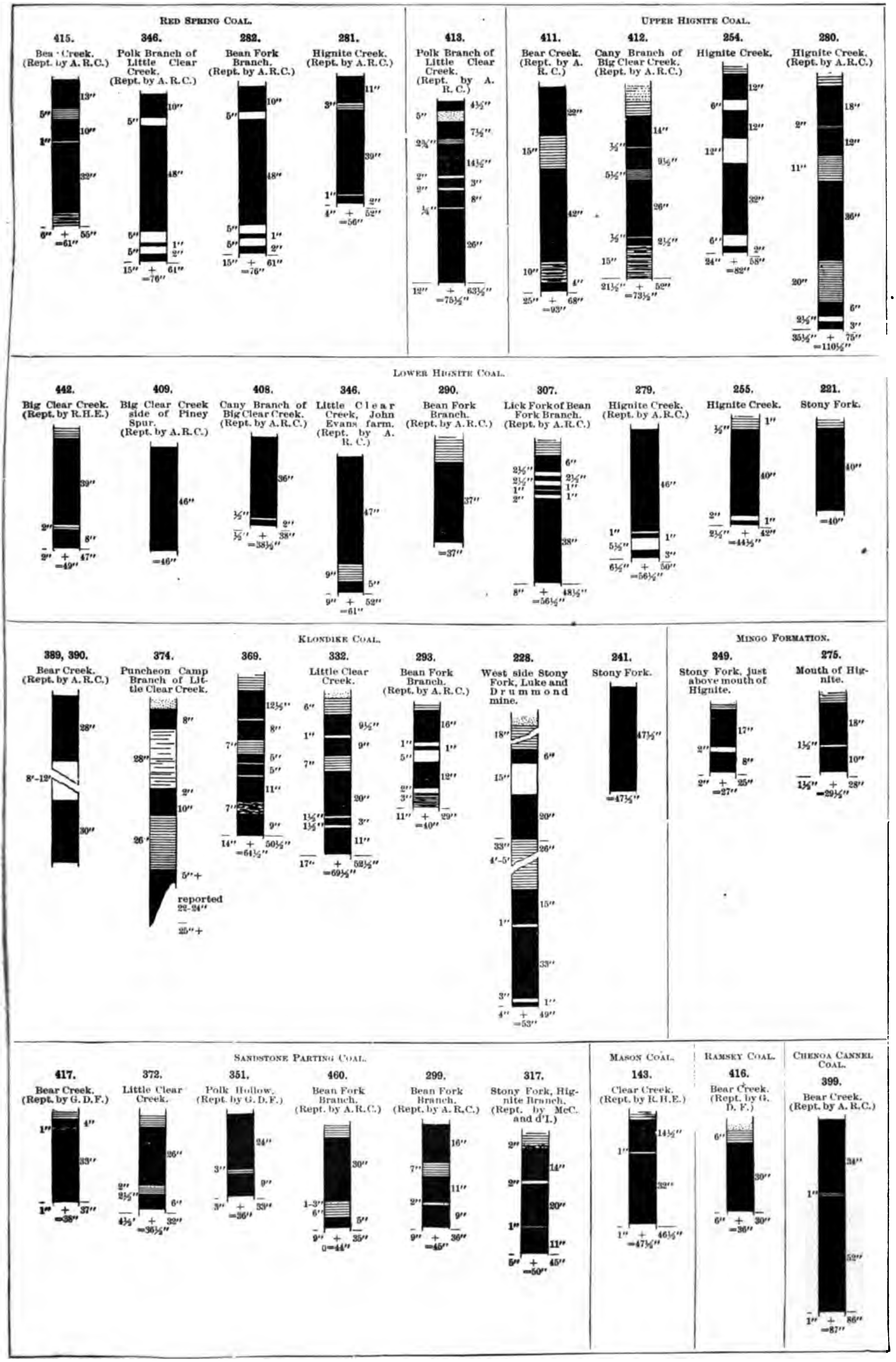
No. on map.	Stratum.	Thickness.		Total thickness of section.	
		Ft.	*in.*	*Ft.*	*in.*
394	Coal	1	6	1,047	6
	Interval, cannel shale	?15	0	1,062	6
395	Coal, Sandstone Parting, Buckeye Spring	2	7	1,065	1
	Interval	130	0	1,195	1
396	Coal, thin				
	Interval	100	0	1,295	1
397	Coal, thin				
	Interval	45	0	1,340	1
398	Coal, thin				
	Interval	50	0	1,390	1
399	Coal, Chenoa cannel	5	9	1,395	10

There appears to be considerable variation in the various reports made on the Bear Creek area.

In a report to the Log Mountain Coal, Coke, and Timber Company by Mr. G. D. Fitzhugh, the following intervals are given:

Section (in part) on Bear Creek.

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
	Shale roof				
420	Coal, Upper Hignite	10	2½	10	2
	Interval, shale roof	12	0	22	2
419	Coal, Lower Hignite	4	3	26	5
	Interval, dark-blue shale roof	290	0	316	5
418	Coal, Poplar Lick	4	10	321	3
	Interval, shale and clay roof	105	0	426	3
417	Coal, Buckeye Spring	3	2	429	5
	Interval, sandstone at bottom	130	0	559	5
	Shale		6	559	11
	Coal, Ramsey (Pl. XIII)	2	6	562	5
	Interval to Chenoa cannel coal	130	0	692	5


RED SPRING COAL.
415. Bear Creek. (Rept. by A. R. C.)
=61"
346. Polk Branch of Little Clear Creek. (Rept. by A. R. C.)
=76"
282. Bean Fork Branch. (Rept. by A. R. C.)
=76"
281. Hignite Creek. (Rept. by A. R. C.)
=56"
413. Polk Branch of Little Clear Creek. (Rept. by A. R. C.)
=75½"
UPPER HIGNITE COAL.
411. Bear Creek. (Rept. by A. R. C.)
=93"
412. Cany Branch of Big Clear Creek. (Rept. by A. R. C.)
=73½"
254. Hignite Creek.
=82"
280. Hignite Creek. (Rept. by A. R. C.)
=110½"
LOWER HIGNITE COAL.
442. Big Clear Creek. (Rept. by R. H. E.)
=49"
409. Big Clear Creek side of Piney Spur. (Rept. by A. R. C.)
=46"
408. Cany Branch of Big Clear Creek. (Rept. by A. R. C.)
=38½"
346. Little Clear Creek, John Evans farm. (Rept. by A. R. C.)
=61"
290. Bean Fork Branch. (Rept. by A. R. C.)
=37"
307. Lick Fork of Bean Fork Branch. (Rept. by A. R. C.)
=56½"
279. Hignite Creek. (Rept. by A. R. C.)
=56½"
255. Hignite Creek.
=44½"
221. Stony Fork.
=40"
KLONDIKE COAL.
389, 390. Bear Creek. (Rept. by A. R. C.)
8'-12'
374. Puncheon Camp Branch of Little Clear Creek.
reported 22-24"
25"+
369.
=64½"
332. Little Clear Creek.
=69½"
293. Bean Fork Branch. (Rept. by A. R. C.)
=40"
228. West side Stony Fork, Luke and Drummond mine.
4'-5'
=53"
241. Stony Fork.
=47½"
MINGO FORMATION.
249. Stony Fork, just above mouth of Hignite.
=27"
275. Mouth of Hignite.
=29½"
SANDSTONE PARTING COAL.
417. Bear Creek. (Rept. by G. D. F.)
=38"
372. Little Clear Creek.
=36½"
351. Polk Hollow. (Rept. by G. D. F.)
=36"
460. Bean Fork Branch. (Rept. by A. R. C.)
=44"
299. Bean Fork Branch. (Rept. by A. R. C.)
=45"
317. Stony Fork, Hignite Branch. (Rept. by McC. and d'I.)
=50"
MASON COAL.
143. Clear Creek. (Rept. by R. H. E.)
=47½"
RAMSEY COAL.
416. Bear Creek. (Rept. by G. D. F.)
=36"
CHENOA CANNEL COAL.
399. Bear Creek. (Rept. by A. R. C.)
=87"

COAL SECTIONS, STONY FORK—CLEAR CREEK DISTRICT.

Another report to the same company by Mr. R. H. Elliott gives still other intervals.

Coals and intervals on Bear Creek.

No. on map.	Stratum.	Thickness of interval.	Total thickness of intervals.
		Feet.	*Feet.*
	Coal, Red Spring.		
	Interval	355	355
	Coal, Upper Hignite.		
	Interval	25	380
442	Coal, Lower Hignite. (See Pl. XIII.)		
	Interval	208	588
	Coal, Poplar Lick.		
	Interval	157	745
	Coal, Buckeye Spring.		
	Interval	110	855
	Coal, Ralston.		
	Interval	20	875
443	Coal, Mason. (See Pl. XIII.)		
	Interval	405	1,280
	Coal, Chenoa cannel.		

In May, 1896, a drilling was made for oil on Bear Creek by the Log Mountain Coal, Coke, and Timber Company. The record is kindly furnished by their successor, the Louisville Property Company. This drilling started at 81 feet above the bottom of the Mason coal and was reported as starting "about 225 feet" below the Poplar Lick coal. The record as given by the drillers is as follows:

Record of oil well drilled on Louisville Property Company's lands near Chenoa, Ky.

Stratum.	Thickness.	Total.
	Feet.	*Feet.*
Clay	27	27
Slate	45	72
Sandstone, brown	5	77
Bituminous coal, Mason seam	4	81
Slate	10	91
Sandstone, with water	36	127
Slate	5	132
Sandstone, white	37	169
Slate	76	245
Bituminous coal, "supposed Blue Gem?"	4	249
Slate and shale	60	309
Bituminous coal	2	311
Slate	20	331
Bituminous coal	2	333
Slate	40	373
Sandstone, with water	10	383
Slate	28	411
Bear Creek cannel coal; "Chenoa" coal	4	415
Fire clay	2	417
Slate	37	454
Sandstone	30	484
Slate	8	492

Record of oil well drilled on Louisville Property Company's lands near Chenoa, Ky.—Continued.

Stratum.	Thickness.	Total.
	Feet.	*Feet.*
Sandstone, black	9	501
Slate and shale	90	591
Sandstone, black	22	613
Slate	35	648
Sandstone, black	5	653
Slate	5	658
Sandstone, white	11	669
Slate	3	672
Sandstone, white	11	683
Slate	30	713
Sandstone, gray	20	733
Sandstone, white	45	778
Slate	15	793
Sandstone, dark	10	803
Slate	35	838
Sandstone, dark	2	840
Slate	35	875
Sandstone, dark	10	885
Slate	15	900
Sandstone, white; Yellow Creek sandstone?	50	950
Slate	38	988
Sandstone, Naese, top of Lee formation	256	1,244
Slate	4	1,248
Sandstone, white	84	1,332
Bituminous coal	4	1,336
Sandstone, white	176	1,512
Slate	5	1,517
Sandstone, white	111	1,628
Slate	5	1,633
Sandstone, white	74	1,707
Bituminous coal	2	1,709
Sandstone, white	72	1,781
Bituminous coal	6	1,787
Sandstone, white	30	1,817

Along the lower course of Clear Creek the Naese sandstone makes cliffs over 130 feet high, and its bottom is not exposed. It therefore seems probable that the sandstone reported 256 feet thick represents that sandstone and the top of the Lee. The 50 feet of sandstone 38 feet above would correspond with the Yellow Creek sandstone. According to that correlation, on Bear Creek the top of the Lee is 1,211 feet below the Poplar Lick coal. The top of the Lee is not exposed on Bennett Fork nor on Bear Creek, nor are the correlations of the Mingo coal with any of the coals of Bear Creek or the Chenoa cannel coal with any of the coals on Bennett Fork certain. A comparison of the intervals between the coals below the Poplar Lick indicates that these intervals decrease from Bennett Fork to Bear Creek and that the Mingo coal occupies about the position of the Mason coal on Bear Creek and the Chenoa cannel coal comes at about the horizon of the Bennett Fork coal. While it is possible that exact correlation between the coals at those horizons exists, with present data such correlation can not be asserted. The following table shows the thinning of the spaces mentioned from south to north:

Sections in several valleys in other parts of the district are given below:

Section (compiled) on Little Clear Creek.

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
	Interval from top of mountain, shale and sandstone	160	0	160	0
326	Coal, Red Spring	5	0	165	0
	Interval	210	0	375	0
327	Coal	5	7	380	7
	Interval	200	0	580	7
328	Coal				
	Interval	80	0	660	7
329	Coal	2	2	662	9
	Interval	25	0	687	9
330	Coal				
	Interval	30	0	717	9
331	Coal, Lower Hignite	4	1	721	10
	Interval	185	0	906	10
332	Coal, Klondike	4	4	911	2
	Interval	110	0	1,021	2
333	Coal, Poplar Lick	4	4	1,025	6
	Interval	180	0	1,205	6
334	Coal, Sandstone Parting (Buckeye Spring)	2	3	1,207	9
	Interval	30	0	1,237	9
366	Coal, bloom				
	Interval, sandstone and hidden	60	0	1,297	9
365	Coal, bloom				
	Interval, shale	90	0	1,387	9
364	Coal, bloom (Mingo?)				
	Interval, shale	50	0	1,437	9
363	Coal, bloom				
	Interval, sandstone and shale	90	0	1,527	9
362	Coal, Miracle	2	6	1,530	3
	Interval	90	0	1,620	3
361	Coal, bloom				
	Interval	120	0	1,740	3
359	Coal	1	5	1,741	8
	Interval, to mouth of Ben Fork	30	0	1,771	8

coal, as correlated in the oil well. This is somewhat more than the measurement obtained from outcrops on Cany Fork or from the outcrops in the valley of Little Clear Creek, and if correct would indicate comparatively little thinning between Bennett Fork and Clear Creek. The same map gives the elevation of the cannel coal at the head of the mine where it is but a short distance from the outcrop of the Poplar Lick coal as 858 feet below the Poplar Lick coal, which agrees in a general way with the assumed thickness of the Mingo formation in this district. These figures seem to confirm the correlations made above that the Mason coal is about at the horizon of the Mingo coal and the cannel coal about at the horizon of the Bennett Fork coal.

The lower part of the above section was obtained between the mouth of Ben Fork and Webb Gap. Along the main stream the Fork Ridge sandstone and the sandstone 100 feet lower make small cliffs. The Fork Ridge sandstone is thought to come just below coal No. 363 of the above section. On the main stream the vertical distance between the Poplar Lick and Klondike coal is—from 75 to 100 feet; that between the Poplar Lick and the Sandstone Parting coal below is from 140 to 160 feet, and that from the Sandstone Parting coal to the top of the Fork Ridge sandstone is 150 feet. A sandstone that is thought to immediately underlie the Red Spring coal makes prominent cliffs all around the top of the mountains at the head of this creek.

Section on Bean Fork Branch of Yellow Creek (A. R. Crandall).

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
	Interval to top of ridge	70	0	70	0
282	Coal, Red Spring	5	1	75	1
	Interval	20	0	95	1
283	Coal				
	Interval, contains cliff-making sandstone	80	0	175	1
284	Coal				
	Interval	60	0	235	1
285	Coal		6+	235	7+
	Interval	50	0	285	7+
286	Coal				
	Interval	50	0	335	7
287	Coal				
	Interval	35	0	370	7
288	Coal		8	371	3
	Interval	75	0	446	3
289	Coal, cannel shale				
	Interval	60	0	506	3
290	Coal, Lower Hignite	3	1	509	4
	Interval	55	0	564	4
291	Coal		1	564	8
	Interval	70	0	634	8
292	Coal	1	1	635	9
	Interval	65	0	670	9
293	Coal	2	1	673	2
	Interval	40	0	713	2
294	Coal		9	713	11
	Interval	85	0	798	11
295	Coal	1	0	799	11
	Interval	45	0	844	11
296	Coal, Poplar Lick	3	3	847	2
	Interval	65	0	913	2

Section on Hignite Creek—Continued.

Stratum.	Thickness.		Total thickness.	
	Ft.	*in.*	*Ft.*	*in.*
Sandstone, Fork Ridge, makes cliffs	30+	0	1,664	7
Interval	150	0	1,814	7
Coal	2	6	1,817	1
Shale	25	0	1,842	1
Coal		6	1,842	7
Sandstone and shale	60	0	1,902	7
Coal	1	6	1,904	1
Interval to mouth of creek	20	0	1,924	1

Section on Rockhouse Branch of Stony Fork.

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
	Interval from top of Log Mountains	1,200	0	1,208	0
244	Coal, Lower Hignite(?)	2	10	1,202	10
	Interval	50	0	1,252	10
	Sandstone, cliff making	40	0	1,292	10
246	Coal	1	8	1,294	6
	Interval, sandy shale, sandstone, and shale	30	0	1,324	6
247	Coal	1	2	1,325	8
	Interval	40	0	1,365	8
245	Coal	1	11	1,367	7
	Interval	115	0	1,482	7
248	Coal, Poplar Lick	5	0	1,487	7
	Interval	150		1,637	7
251	Coal, Sandstone Parting(?)	3	0	1,640	7
	Interval	100	0	1,740	7
236	Coal	1	6	1,742	1
	Interval (Mingo coal, 40? feet from bottom, not seen)	80	0	1,922	1
	Sandstone, massive, cross-bedded, Fork Ridge	50	0	1,972	1
252	Coal	1	9	1,970	9
	Interval to mouth of creek	30	0	2,000	9

Several openings on the Poplar Lick coal had the position of that coal as mapped by the Louisville Property Company.

Section on head of Stony Fork.

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
	Interval from top of mountain	780	0	780	0
221	Coal, Lower Hignite	3	4	783	4
	Sandstone, massive	40	0	823	4
	Interval, largely sandstone	170	0	993	4
	Coal	2+	0	995	4
	Shale	5	0	1,000	4
228	Coal, Klondike?	3	5	1,003	9
	Interval	45	0	1,048	9
223	Coal	1	4	1,050	1
	Interval	20	0	1,070	1
224	Coal	0	10	1,070	11
	Interval	40	0	1,110	11
229	Coal, Poplar Lick	5+	0	1,115	11
	Interval	90	0	1,205	11
231	Coal	0	3	1,206	2
	Interval, shale	70	0	1,276	2
232	Coal	1	6	1,277	8
	Interval, shale	30	0	1,307	8
233	Coal, bloom				
	Interval, shale and sandstone	35	0	1,342	8
234	Coal	1	0	1,343	8
	Sandstone	20	0	1,363	8
238	Coal	1	6	1,365	2
	Interval	70	0	1,435	2
	Coal(?) (estimated position of Mingo coal not found)				
	Interval	40	0	1,475	2
	Sandstone, Fork Ridge, massive, cliff making	40	0	1,515	2
252	Coal	1	9	1,516	11
	Interval to mouth of Coal Branch	30	0	1,546	11

Though these last two sections differ in detail they seem to be in general agreement, if the Poplar Lick coal is used as a key stratum. On these streams the Poplar Lick coal appears to be about 110 feet below what is correlated as the Klondike coal, and about 320 feet below the coal that is considered to be same as the Lower Hignite on Hignite Creek. On Stony Fork the most prominent cliff-making sandstone above the Fork Ridge occurs just below the Lower Hignite coal.

The Fork Ridge sandstone, which was used as a key rock in the Bennett Fork district, can also be traced through part of this district. It crosses Stony Fork a short distance above the mouth of Coal Branch, and from there can be traced down on the north side of Stony Fork to the flat area around Middlesboro. The lower sandstone keeps about the same distance below, 100 to 120 feet, along the flank of the mountains. At the mouth of Hignite Creek the top of the Fork Ridge sandstone is about 230 feet above the mouth of the creek, or nearly 1,600 feet above sea level. Up Hignite Creek it is carried down by the northwest dip, so that it crosses the creek at a much lower elevation. These two sandstones are prominent on Bean Fork Branch, the top of the Fork Ridge sandstone crossing the creek bed at an elevation of about 1,670 feet by barometer. On Little Clear Creek the two sandstones are again seen in places, the top of the upper sandstone crossing the headwaters of Little Clear Creek at an elevation of about 1,590 feet. These sandstones were not certainly recognized on Clear Creek. These sandstones and the facings on the Poplar Lick coal were the main factors in determining the stratigraphy and structure of this district.

So far as known no coals have been found in the Lee formation as exposed in this district in Pine Mountain. Several thick coals are reported in the oil-well drilling. But such data are not usually reliable as to thickness of coals.

COALS.

COALS OF MINGO FORMATION.

The Mingo formation is defined in this area as running from the bottom of the Poplar Lick coal to the bottom of the Chenoa cannel coal of Bear Creek. It contains the Sandstone Parting coal, or, as it has frequently been called in this district, the "Buckeye Spring" coal, the Mason coal, which is thought to be the representative of the Mingo coal, the Chenoa cannel coal, and possibly one or two coals between the Mingo coal and Chenoa cannel coal which may locally reach a workable thickness. The Chenoa cannel coal is thought to have about the same stratigraphic position as the Bennett Fork coal, though it can not be asserted that they are actually at the same horizon.

CHENOA CANNEL COAL.

This coal was mined extensively at the Mary Hull mine at Chenoa from November, 1893, until the mine was abandoned in July, 1899. The cannel coal here, as is usual with cannel coal, proved to be in a basin, which could be mined for a width of about 600 feet and which was followed down the dip for a distance of about 4,000 feet. In the first 400 or 500 feet the dip is about 8°, in the next 400 or 500 feet its dip is 5°, gradually decreasing to 2° or less. On account of the position of the coal and of the fact that it has been entered from the upper end of the dip, the cost of working necessarily increased constantly until it became prohibitive. At the time operations ceased plans were on foot for making a new opening by a slope, in order to reach the coal near the present face. This coal shows a total section of over 7 feet in the center of the basin, thinning out to the edges of the basin. The upper part is bituminous while the lower part is cannel. One section reported by Mr. Crandall, gave 34 inches of bituminous coal on top, separated by 1 inch of charcoal from 52 inches of cannel coal at the bottom. Near the ventilating furnace the section showed 7 inches of cannel coal, 9½ inches of bituminous coal, 18 inches of hard clay shale, 17 inches of bituminous coal, and 14 inches of cannel coal—a total of 97 inches. Usually there is a single block of bituminous coal above the shale parting which may resemble cannel at the top or bottom. The thickness of the cannel coal bench ranges from about 55 inches in the center of the basin to 30 inches at the sides. The following analyses are by Dr. Robert Peter:

Analyses of Chenoa coal.

Constituent.	Cannel.	Bituminous.
Moisture	1.00	1.70
Volatile combustible matter	51.60	32.60
Fixed carbon	40.40	62.30
Ash	7.00	3.40
Sulphur	.739	.684

From the nature and origin of cannel coal it will be impossible to predict the further extent of this coal. According to the usually accepted theory of its origin, cannel coal is always confined to more or less limited basins, often showing a good thickness in the center of the basin, but usually running out to a feather edge on the margin. The further extent of this coal can be determined only by drilling; or, by driving entries from the old works, if that is possible. No outcrop of this coal showing similar characters has been noted on Little Clear Creek, while its horizon is entirely below drainage on Stony Fork.

MINGO COAL.

No outcrop that could be certainly recognized as the Mingo coal was seen on Stony Fork or its branches. At several places evidence of a coal having been faced at this horizon was found, but when visited all of the facings had fallen in, suggesting that the coal had not proved of workable thickness. On Bean Fork Branch this coal may be represented by 11 inches of coal with 5 inches of cannel shale 3 inches above, which Mr. Crandall gives in his section on Bean Fork Branch (301), or it may be represented by the 26 inches of coal 100 feet higher (300). On Little Clear Creek a coal at what was thought to be the horizon of the Mingo coal was reported; being a low-grade cannel, its thickness was not obtained. On Clear Creek Mr. Elliott states that this seam has a thickness of 47½ inches with a 1-inch parting 14½ inches from the top. He gives 46 inches as the average thickness of the coal as shown by three measurements. The Ramsey coal reported on Bear Creek by Mr. Fitzhugh may be the same coal. He gives its thickness as 30 inches. On Bean Fork Branch the coal at this horizon was reported to be 5 feet thick, and at one place appeared to have been opened and worked, but the opening was closed when examined and the report could not be verified. A sample of the Mason coal, representing the entire thickness of the seam, was sent to Mr. Hislop, of Paisley, Scotland, who describes it as follows:

"The coal is black, of considerable luster and brown streak, while in texture it is irregular and resinoid, containing some deposits of charcoal; cross fractures, angular, highly crystalline, and pure in composition, moderately cohesive and compact; on the fire it intumesces and agglomerates; color of ash, brown; thickness of seam, 50 inches, and of very uniform density; mean specific gravity, 1,225 (water, 1,000); weight of one cubic foot, 76.56 pounds."

Chemical analysis of coal on Bear Creek.

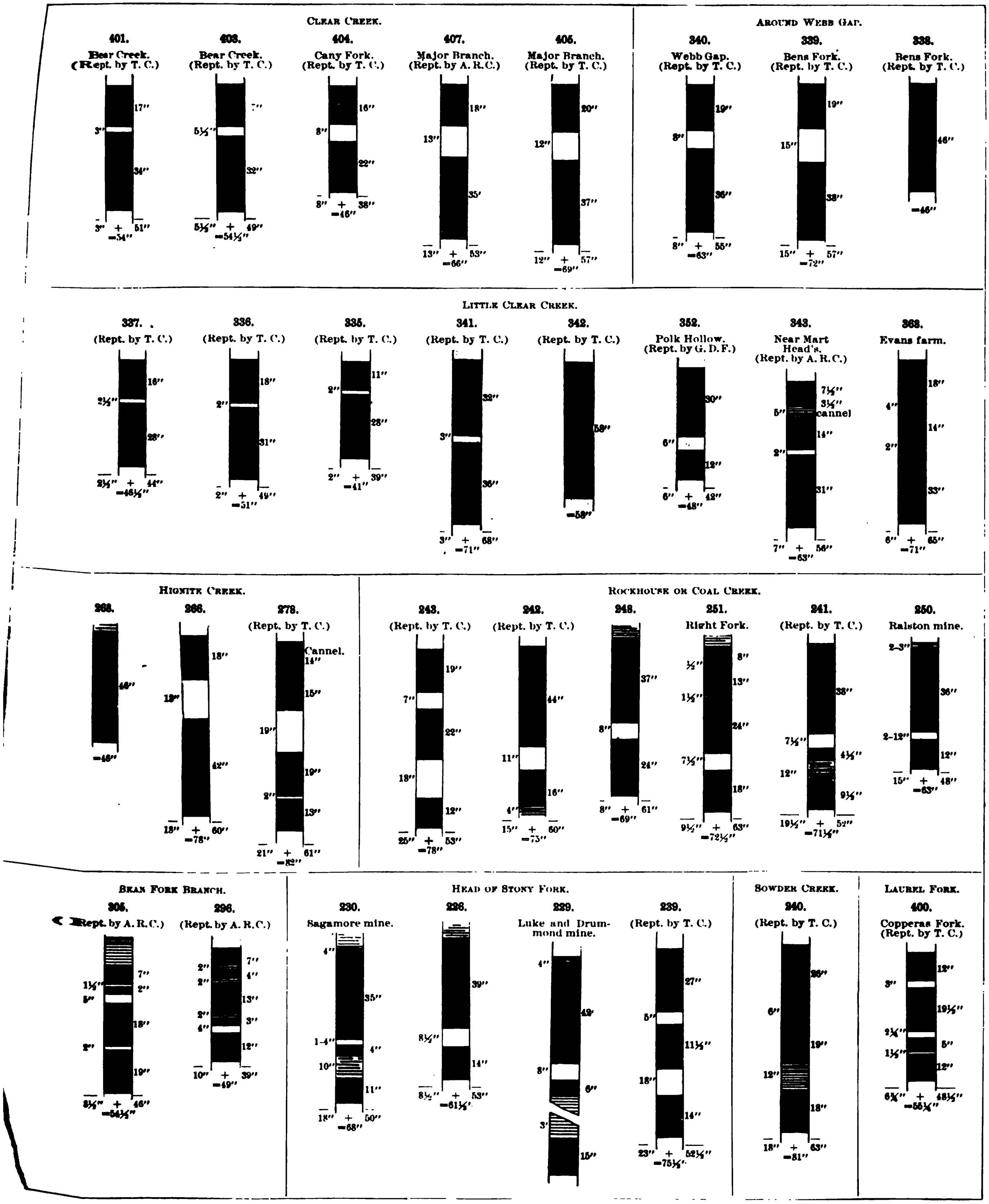
	Per cent.
Moisture	4.35
Volatile combustible matter	33.01
Fixed carbon	61.44
Sulphur	.45
Ash	.75

Mr. Hislop reports that this coal showed the smallest amount of ash and sulphur he had ever obtained in a bituminous coal. On the whole, therefore, this coal may be considered workable in a limited area on Clear Creek side, but elsewhere its workability must be considered doubtful unless further exploration shall show the coal to be better and thicker than it is at present known on the Little Clear Creek and Stony Fork side.

Below the Mingo coal several coals of nearly workable thickness have been opened. Just below the mouth of Coal Branch a coal opened immediately under the Fork Ridge sandstone shows a thickness of only 21 inches, and is separated by 3 feet of shale from the sandstone above. At the mouth of Hignite Creek the coal has a thickness of 29½ inches, and a 1½-inch parting 10 inches from the bottom. This immediately underlies a sandstone. A short distance farther up Stony Fork the same coal shows a thickness of only 27 inches with a 2-inch parting 8 inches from the bottom. On Little Clear Creek what is sometimes called the "Miracle" coal was reported at one place to show a thickness of 40 inches with 3 to 4 inches of clay parting near the top. At another point, supposedly the same coal was reported as 30 inches thick, but only 12 inches were seen. It here has from 2 to 10 inches of clay over it with 5+ feet of sandstone above. On the whole it may be said that as far as found no workable coals exist between the Mingo and the Chenoa cannel.

SANDSTONE PARTING COAL.

Mr. Fitzhugh reports the Sandstone Parting coal (Buckeye Spring) as showing on Bear Creek (417) 38 inches of coal with a 1-inch bench of soft coal 4 inches from the top. Mr. Crandall reports this coal as 2 feet 7 inches thick on Bear Creek (395). On Little Clear Creek this coal has a total thickness of 36½ inches (372). The sandstone parting here is 2 inches thick and 26 inches from the top. Below it are 2½ inches of cannel shale. The roof is a gray shale. The parting here ranges from a sandy or gritty shale to a sandstone. On Polk Hollow Mr. Fitzhugh reports this coal as 36 inches thick with a 3-inch shale parting 24 inches from the top. In the section of the coals at the head of Little Clear Creek Mr. Crandall reports this coal as 7 inches thick (334). On Bean Fork Branch Mr. Crandall reports this coal as 44 inches thick (460). The sandstone parting here is from 1 to 3 inches thick and comes 30 inches from the top; below it is 6 inches of shale. The section here, as will be seen, very closely resembles that on Little Clear Creek. In his sections of the coals on Bean Fork Branch Mr. Crandall makes this coal 45 inches thick with a 7-inch shale parting 16 inches from the top, and with a 2-inch sandstone parting 9 inches from the



SECTIONS OF POPLAR LICK COAL, STONY FORK—CLEAR CREEK DISTRICT.

Scale: 1 inch=5 feet.

Another report to the same company by Mr. R. H. Elliott gives still other intervals.

Coals and intervals on Bear Creek.

No. on map.	Stratum.	Thickness of interval.	Total thickness of intervals.
		Feet.	*Feet.*
	Coal, Red Spring.		
	Interval	355	355
	Coal, Upper Hignite.		
	Interval	25	380
442	Coal, Lower Hignite. (See Pl. XIII.)		
	Interval	208	588
	Coal, Poplar Lick.		
	Interval	157	745
	Coal, Buckeye Spring.		
	Interval	110	855
	Coal, Ralston.		
	Interval	20	875
443	Coal, Mason. (See Pl. XIII.)		
	Interval	405	1,280
	Coal, Chenoa cannel.		

In May, 1896, a drilling was made for oil on Bear Creek by the Log Mountain Coal, Coke, and Timber Company. The record is kindly furnished by their successor, the Louisville Property Company. This drilling started at 81 feet above the bottom of the Mason coal and was reported as starting "about 225 feet" below the Poplar Lick coal. The record as given by the drillers is as follows:

Record of oil well drilled on Louisville Property Company's lands near Chenoa, Ky.

Stratum.	Thickness.	Total.
	Feet.	*Feet.*
Clay	27	27
Slate	45	72
Sandstone, brown	5	77
Bituminous coal, Mason seam	4	81
Slate	10	91
Sandstone, with water	36	127
Slate	5	132
Sandstone, white	37	169
Slate	76	245
Bituminous coal, "supposed Blue Gem?"	4	249
Slate and shale	60	309
Bituminous coal	2	311
Slate	20	331
Bituminous coal	2	333
Slate	40	373
Sandstone, with water	10	383
Slate	28	411
Bear Creek cannel coal; "Chenoa" coal	4	415
Fire clay	2	417
Slate	37	454
Sandstone	30	484
Slate	8	492

Record of oil well drilled on Louisville Property Company's lands near Chenoa, Ky.—Continued.

Stratum.	Thickness.	Total.
	Feet.	*Feet.*
Sandstone, black	9	501
Slate and shale	90	591
Sandstone, black	22	613
Slate	35	648
Sandstone, black	5	653
Slate	5	658
Sandstone, white	11	669
Slate	3	672
Sandstone, white	11	683
Slate	30	713
Sandstone, gray	20	733
Sandstone, white	45	778
Slate	15	793
Sandstone, dark	10	803
Slate	35	838
Sandstone, dark	2	840
Slate	35	875
Sandstone, dark	10	885
Slate	15	900
Sandstone, white; Yellow Creek sandstone?	50	950
Slate	38	988
Sandstone, Naese, top of Lee formation	256	1,244
Slate	4	1,248
Sandstone, white	84	1,332
Bituminous coal	4	1,336
Sandstone, white	176	1,512
Slate	5	1,517
Sandstone, white	111	1,628
Slate	5	1,633
Sandstone, white	74	1,707
Bituminous coal	2	1,709
Sandstone, white	72	1,781
Bituminous coal	6	1,787
Sandstone, white	30	1,817

Along the lower course of Clear Creek the Naese sandstone makes cliffs over 130 feet high, and its bottom is not exposed. It therefore seems probable that the sandstone reported 256 feet thick represents that sandstone and the top of the Lee. The 50 feet of sandstone 38 feet above would correspond with the Yellow Creek sandstone. According to that correlation, on Bear Creek the top of the Lee is 1,211 feet below the Poplar Lick coal. The top of the Lee is not exposed on Bennett Fork nor on Bear Creek, nor are the correlations of the Mingo coal with any of the coals of Bear Creek or the Chenoa cannel coal with any of the coals on Bennett Fork certain. A comparison of the intervals between the coals below the Poplar Lick indicates that these intervals decrease from Bennett Fork to Bear Creek and that the Mingo coal occupies about the position of the Mason coal on Bear Creek and the Chenoa cannel coal comes at about the horizon of the Bennett Fork coal. While it is possible that exact correlation between the coals at those horizons exists, with present data such correlation can not be asserted. The following table shows the thinning of the spaces mentioned from south to north:

Comparison of intervals between coals on Bennett Fork and Bear Creek.

	Bennett Fork.	Slickrock Branch.	Little Clear Creek.	Bear Creek (drilling).
	Feet.	*Feet.*	*Feet.*	*Feet.*
A	230	210	210	
B	285	210	140	
C	515	420	350	306
D	440			334
E	560 ?			571

A. Interval between Poplar Lick coal and Sandstone Parting (Buckeye Spring) coal.

B. Interval between Sandstone Parting and Mingo (Mason) coal.

C. Interval between Poplar Lick and Mingo (Mason) coal.

D. Interval between Mingo coal and Bennett Fork coal on Bennett Fork, and Mason coal and Chenoa cannel coal on Bear Creek.

E. Interval from top of Lee sandstone to Bennett Fork or Chenoa cannel coal (hypothetical on Bennett Fork). This interval of 560 feet is based on a comparison of the intervals between the coals on Bennett Fork and those to the east in Jackson Mountain, as shown below.

Intervals between coals on Bennett Fork and Jackson Mountain.

	Feet.
Top of Jesse sandstone to Wallins Creek coal	320
Top of sandstone just under Lower Hignite coal to Poplar Lick coal	340
Wallins Creek coal to Creech coal	460
Poplar Lick coal to Mingo coal	515
Creech coal to Hance coal	500
Mingo coal to Bennett Fork coal	440
Hance coal to top of Lee sandstone	560
Bennett Fork coal to top of Lee sandstone	500 + (?)

The above facts are among those which have led us to believe that the Chenoa cannel coal is about at the horizon of the Bennett Fork coal on Bennett Fork, of the Hance coal on Hance Ridge, and of the Harlan coal of the Harlan district, and so has been taken as the top of the Hance formation in the Clear Creek district. Also that the Mason coal is about at the horizon of the Mingo coal, and the Mingo coal in turn at the horizon of the Creech coal on Jackson Mountain; and that the Poplar Lick coal of this region is at the horizon of the Wallins Creek coal of the eastern part of the field.[a]

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[a] Since the above was written a map has been received from the Louisville Property Company upon which are given some actual elevations on the Hignite coal, the Poplar Lick coal, the Sandstone Parting coal, and the Mason coal. Taking points at which there are elevations on two coals near each other and approximately in the strike of the rocks, we are able to get differences of elevation which probably give with considerable accuracy the vertical intervals between these coals. According to these measurements the interval between the Lower Hignite coal and the Poplar Lick coal is 280 feet on Bear Creek, 278 feet on Cany Fork of Clear Creek, 337 feet on Stony Fork, and 295 feet on Hignite Creek. In the last case the measurement gives the vertical distance between two outcrops some distance apart near the bed of the stream so that the stratigraphic interval should be somewhat greater. From this it would appear that the interval from the Hignite coal to the Poplar Lick coal is somewhat less than 350 feet in the Stony Fork basin and somewhat less than 300 feet in the Clear Creek basin. From the Poplar Lick to the Sandstone Parting coal similar measurements give 152 feet on Bear Creek, 175 feet on Cany Fork of Clear Creek, 141 feet on Ben Fork of Little Clear Creek, 168 feet on the headwaters of Little Clear Creek, 178 on Coal Creek, and 190 on Stony Fork. From the Sandstone Parting coal to the Mason coal on Cany Fork is 221 feet; on Ben Fork, 259 feet, the total interval from the Poplar Lick coal to the Mason coal on Ben Fork being 400 feet. On Laurel Branch the interval from the Poplar Lick to the Mason coal is 365 feet. Several measurements on Stony Fork from the Hignite to the Sandstone Parting coal gave an average of 540 feet.

According to this map the top of the oil well referred to above is 354 feet below the outcrop of the Poplar Lick coal, a few rods to the east and in the line of strike, which would make 435 feet from the Poplar Lick to the Mason

Sections in several valleys in other parts of the district are given below:

Section (compiled) on Little Clear Creek.

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
	Interval from top of mountain, shale and sandstone	160	0	160	0
326	Coal, Red Spring	5	0	165	0
	Interval	210	0	375	0
327	Coal	5	7	380	7
	Interval	200	0	580	7
328	Coal	.....	.....	.....	.....
	Interval	80	0	660	7
329	Coal	2	2	662	9
	Interval	25	0	687	9
330	Coal	.....	.....	.....	.....
	Interval	30	0	717	9
331	Coal, Lower Hignite	4	1	721	10
	Interval	185	0	906	10
332	Coal, Klondike	4	4	911	2
	Interval	110	0	1,021	2
333	Coal, Poplar Lick	4	4	1,025	6
	Interval	180	0	1,205	6
334	Coal, Sandstone Parting (Buckeye Spring)	2	3	1,207	9
	Interval	30	0	1,237	9
366	Coal, bloom	.....	.....	.....	.....
	Interval, sandstone and hidden	60	0	1,297	9
365	Coal, bloom	.....	.....	.....	.....
	Interval, shale	90	0	1,387	9
364	Coal, bloom (Mingo?)	.....	.....	.....	.....
	Interval, shale	50	0	1,437	9
363	Coal, bloom	.....	.....	.....	.....
	Interval, sandstone and shale	90	0	1,527	9
362	Coal, Miracle	2	6	1,530	3
	Interval	90	0	1,620	3
361	Coal, bloom	.....	.....	.....	.....
	Interval	120	0	1,740	3
359	Coal	1	5	1,741	8
	Interval, to mouth of Ben Fork	30	0	1,771	8

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coal, as correlated in the oil well. This is somewhat more than the measurement obtained from outcrops on Cany Fork or from the outcrops in the valley of Little Clear Creek, and if correct would indicate comparatively little thinning between Bennett Fork and Clear Creek. The same map gives the elevation of the cannel coal at the head of the mine where it is but a short distance from the outcrop of the Poplar Lick coal as 858 feet below the Poplar Lick coal, which agrees in a general way with the assumed thickness of the Mingo formation in this district. These figures seem to confirm the correlations made above that the Mason coal is about at the horizon of the Mingo coal and the cannel coal about at the horizon of the Bennett Fork coal.

The lower part of the above section was obtained between the mouth of Ben Fork and Webb Gap. Along the main stream the Fork Ridge sandstone and the sandstone 100 feet lower make small cliffs. The Fork Ridge sandstone is thought to come just below coal No. 363 of the above section. On the main stream the vertical distance between the Poplar Lick and Klondike coal is—from 75 to 100 feet; that between the Poplar Lick and the Sandstone Parting coal below is from 140 to 160 feet, and that from the Sandstone Parting coal to the top of the Fork Ridge sandstone is 150 feet. A sandstone that is thought to immediately underlie the Red Spring coal makes prominent cliffs all around the top of the mountains at the head of this creek.

Section on Bean Fork Branch of Yellow Creek (A. R. Crandall).

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
	Interval to top of ridge	70	0	70	0
282	Coal, Red Spring	5	1	75	1
	Interval	20	0	95	1
283	Coal				
	Interval, contains cliff-making sandstone	80	0	175	1
284	Coal				
	Interval	60	0	235	1
285	Coal		6+	235	7+
	Interval	50	0	285	7+
286	Coal				
	Interval	50	0	335	7
287	Coal				
	Interval	35	0	370	7
288	Coal		8	371	3
	Interval	75	0	446	3
289	Coal, cannel shale				
	Interval	60	0	506	3
290	Coal, Lower Hignite	3	1	509	4
	Interval	55	0	564	4
291	Coal		1	564	8
	Interval	70	0	634	8
292	Coal	1	1	635	9
	Interval	65	0	670	9
293	Coal	2	1	673	2
	Interval	40	0	713	2
294	Coal		9	713	11
	Interval	85	0	798	11
295	Coal	1	0	799	11
	Interval	45	0	844	11
296	Coal, Poplar Lick	3	3	847	2
	Interval	65	0	913	2

Section on Bean Fork Branch of Yellow Creek—Continued.

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
297	Coal	1	3	914	5
	Interval	100	0	1,014	5
298	Coal	1	4	1,015	9
	Interval	5	0	1,020	9
299	Coal, Sandstone Parting	3+	0	1,023+	9
	Interval	115	0	1,138	9
300	Coal	2	2	1,140	11
	Interval	115	0	1,255	11
301	Coal		11+	1,256	10
	Interval	50	0	1,306	10
302	Coal	1	3	1,308	1
	Interval	120	0	1,428	1
303	Coal				
	Interval to mouth of Bean Fork Branch	50	0	1,478	1

This section has a total thickness of about 1,500 feet. The topographic map and the sections up Bean Fork Branch show that the strata have a thickness of nearly 2,000 feet vertical interval from the mouth to the top of Canada Peak, and as a coal bloom, taken to be of the Red Spring coal, occurs about 100 feet below the top of Canada Peak, it is judged that this section as given is 500 feet too short. The discrepancy between this section and our sections appeared to occur mainly at the base. In this section the coal, that is taken as the representative of the Mingo coal, occurs 220 feet above the mouth of the stream, while the position of the Fork Ridge sandstone, as traced into this valley, gave the elevation of the Mingo coal as 640 feet above the mouth of the creek. This difference of 420 feet is nearly equal to the shortage in the section.

The section of Hignite Creek given on Pl. XII is likewise subject to question. The section given is the one obtained during the present survey. Some of the coal sections were obtained by side climbs, and on account of the dips and the changes in the character of the rocks it was in many cases difficult to join such side sections to the section obtained along the bed of the main stream. Thus a coal on the bank several hundred feet above the channel of the stream can not always be recognized in the bed of the main stream a mile or two farther up, mainly on account of the lack of exposures between.

A map prepared by the Louisville Property Company shows that the Poplar Lick coal on Hignite Creek is 659 feet above the mouth. Our measurements by barometer gave 690 feet as the elevation of the Poplar Lick coal above the mouth. Messrs. McCreath and d'Invilliers give the section of a coal measured on Hignite Creek which has the characteristic sandstone parting of the Sandstone Parting coal. This, they report, is at an elevation of 650 feet above Stony Fork. If the last section was near the southern face of the divide east of Hignite Creek, as reported by

McCreath and d'Invilliers, it is possible that the dip would carry it a proper distance below the Poplar Lick coal at the point where the horizon of the latter crosses Hignite Creek. Again there is a variation in the measurements of the interval between the Poplar Lick coal and the Lower Hignite; ours, by barometer, gave almost 400 feet; Mr. Justice, of the Louisville Property Company, got 226.25 feet. Whether this difference is due to measurements between different coals or to errors in one of the measurements it is not possible to say. Accordingly the following section is given with some question:

Section on Hignite Creek.

Stratum.	Thickness.		Total thickness.	
	Ft.	*in.*	*Ft.*	*in.*
Top of Log Mountains				
Interval	230	0		
Coal, Red Spring	2+	0	232	0
Sandstone, Red Spring, cliff making	40	0	272	0
Interval	460	0	732	0
Coal, Upper Hignite Creek	4	10	736	10
Interval	12	0	748	10
Coal, Lower Hignite	3	6	752	4
Interval	30	0	782	4
Coal	2	0	784	4
Interval, mainly sandstone	120	0	904	4
Coal	[a] 1	1	905	5
Interval, mainly sandstone	30	0	935	5
Coal	1	8	937	1
Shale	15	0	952	1
Coal	1	1	953	2
Shale	10	0	963	2
Coal		8	963	10
Interval, sandstone at top	90	0	1,053	10
Sandstone, cliff making	50	0	1,103	10
Interval	40	0	1,143	10
Coal, Poplar Lick	[b] 6	8	1,150	6
Interval	220	0	1,370	6
Coal		9	1,371	3
Interval	100	0	1,471	3
Coal	1	4	1,472	7
Interval	60	0	1,532	7
Sandstone, cliff making, massive cross-bedded, makes falls at forks of creek	60	0	1,592	7
Coal, estimated position of Mingo coal	2+	0	1,594	7
Interval	40	0	1,634	7
Coal facing fallen in				

[a] 8 inches to 1 foot 1 inch.

[b] 4 feet to 6 feet 8 inches.

Section on Hignite Creek—Continued.

Stratum.	Thickness.		Total thickness.	
	Ft.	*in.*	*Ft.*	*in.*
Sandstone, Fork Ridge, makes cliffs	30+	0	1,664	7
Interval	150	0	1,814	7
Coal	2	6	1,817	1
Shale	25	0	1,842	1
Coal		6	1,842	7
Sandstone and shale	60	0	1,902	7
Coal	1	6	1,904	1
Interval to mouth of creek	20	0	1,924	1

Section on Rockhouse Branch of Stony Fork.

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
	Interval from top of Log Mountains	1,200	0	1,208	0
244	Coal, Lower Hignite(?)	2	10	1,202	10
	Interval	50	0	1,252	10
	Sandstone, cliff making	40	0	1,292	10
246	Coal	1	8	1,294	6
	Interval, sandy shale, sandstone, and shale	30	0	1,324	6
247	Coal	1	2	1,325	8
	Interval	40	0	1,365	8
245	Coal	1	11	1,367	7
	Interval	115	0	1,482	7
248	Coal, Poplar Lick	5	0	1,487	7
	Interval	150		1,637	7
251	Coal, Sandstone Parting(?)	3	0	1,640	7
	Interval	100	0	1,740	7
250	Coal	1	6	1,742	1
	Interval (Mingo coal, 40? feet from bottom, not seen)	80	0	1,922	1
	Sandstone, massive, cross-bedded, Fork Ridge	50	0	1,972	1
252	Coal	1	9	1,970	9
	Interval to mouth of creek	30	0	2,000	9

Several openings on the Poplar Lick coal had the position of that coal as mapped by the Louisville Property Company.

Section on head of Stony Fork.

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
	Interval from top of mountain	780	0	780	0
221	Coal, Lower Hignite	3	4	783	4
	Sandstone, massive	40	0	823	4
	Interval, largely sandstone	170	0	993	4
	Coal	2+	0	995	4
	Shale	5	0	1,000	4
228	Coal, Klondike?	3	5	1,003	9
	Interval	45	0	1,048	9
223	Coal	1	4	1,050	1
	Interval	20	0	1,070	1
224	Coal	0	10	1,070	11
	Interval	40	0	1,110	11
229	Coal, Poplar Lick	5+	0	1,115	11
	Interval	90	0	1,205	11
231	Coal	0	3	1,206	2
	Interval, shale	70	0	1,276	2
232	Coal	1	6	1,277	8
	Interval, shale	30	0	1,307	8
233	Coal, bloom				
	Interval, shale and sandstone	35	0	1,342	8
234	Coal	1	0	1,343	8
	Sandstone	20	0	1,363	8
238	Coal	1	6	1,365	2
	Interval	70	0	1,435	2
	Coal(?) (estimated position of Mingo coal not found)				
	Interval	40	0	1,475	2
	Sandstone, Fork Ridge, massive, cliff making	40	0	1,515	2
252	Coal	1	9	1,516	11
	Interval to mouth of Coal Branch	30	0	1,546	11

Though these last two sections differ in detail they seem to be in general agreement, if the Poplar Lick coal is used as a key stratum. On these streams the Poplar Lick coal appears to be about 110 feet below what is correlated as the Klondike coal, and about 320 feet below the coal that is considered to be same as the Lower Hignite on Hignite Creek. On Stony Fork the most prominent cliff-making sandstone above the Fork Ridge occurs just below the Lower Hignite coal.

The Fork Ridge sandstone, which was used as a key rock in the Bennett Fork district, can also be traced through part of this district. It crosses Stony Fork a short distance above the mouth of Coal Branch, and from there can be traced down on the north side of Stony Fork to the flat area around Middlesboro. The lower sandstone keeps about the same distance below, 100 to 120 feet, along the flank of the mountains. At the mouth of Hignite Creek the top of the Fork Ridge sandstone is about 230 feet above the mouth of the creek, or nearly 1,600 feet above sea level. Up Hignite Creek it is carried down by the northwest dip, so that it crosses the creek at a much lower elevation. These two sandstones are prominent on Bean Fork Branch, the top of the Fork Ridge sandstone crossing the creek bed at an elevation of about 1,670 feet by barometer. On Little Clear Creek the two sandstones are again seen in places, the top of the upper sandstone crossing the headwaters of Little Clear Creek at an elevation of about 1,590 feet. These sandstones were not certainly recognized on Clear Creek. These sandstones and the facings on the Poplar Lick coal were the main factors in determining the stratigraphy and structure of this district.

So far as known no coals have been found in the Lee formation as exposed in this district in Pine Mountain. Several thick coals are reported in the oil-well drilling. But such data are not usually reliable as to thickness of coals.

COALS.

COALS OF MINGO FORMATION.

The Mingo formation is defined in this area as running from the bottom of the Poplar Lick coal to the bottom of the Chenoa cannel coal of Bear Creek. It contains the Sandstone Parting coal, or, as it has frequently been called in this district, the "Buckeye Spring" coal, the Mason coal, which is thought to be the representative of the Mingo coal, the Chenoa cannel coal, and possibly one or two coals between the Mingo coal and Chenoa cannel coal which may locally reach a workable thickness. The Chenoa cannel coal is thought to have about the same stratigraphic position as the Bennett Fork coal, though it can not be asserted that they are actually at the same horizon.

CHENOA CANNEL COAL.

This coal was mined extensively at the Mary Hull mine at Chenoa from November, 1893, until the mine was abandoned in July, 1899. The cannel coal here, as is usual with cannel coal, proved to be in a basin, which could be mined for a width of about 600 feet and which was followed down the dip for a distance of about 4,000 feet. In the first 400 or 500 feet the dip is about 8°, in the next 400 or 500 feet its dip is 5°, gradually decreasing to 2° or less. On account of the position of the coal and of the fact that it has been entered from the upper end of the dip, the cost of working necessarily increased constantly until it became prohibitive. At the time operations ceased plans were on foot for making a new opening by a slope, in order to reach the coal near the present face. This coal shows a total section of over 7 feet in the center of the basin, thinning out to the edges of the basin. The upper part is bituminous while the lower part is cannel. One section reported by Mr. Crandall, gave 34 inches of bituminous coal on top, separated by 1 inch of charcoal from 52 inches of cannel coal at the bottom. Near the ventilating furnace the section showed 7 inches of cannel coal, 9½ inches of bituminous coal, 18 inches of hard clay shale, 17 inches of bituminous coal, and 14 inches of cannel coal—a total of 97 inches. Usually there is a single block of bituminous coal above the shale parting which may resemble cannel at the top or bottom. The thickness of the cannel coal bench ranges from about 55 inches in the center of the basin to 30 inches at the sides. The following analyses are by Dr. Robert Peter:

Analyses of Chenoa coal.

Constituent.	Cannel.	Bituminous.
Moisture	1.00	1.70
Volatile combustible matter	51.60	32.60
Fixed carbon	40.40	62.30
Ash	7.00	3.40
Sulphur	.739	.684

From the nature and origin of cannel coal it will be impossible to predict the further extent of this coal. According to the usually accepted theory of its origin, cannel coal is always confined to more or less limited basins, often showing a good thickness in the center of the basin, but usually running out to a feather edge on the margin. The further extent of this coal can be determined only by drilling; or, by driving entries from the old works, if that is possible. No outcrop of this coal showing similar characters has been noted on Little Clear Creek, while its horizon is entirely below drainage on Stony Fork.

MINGO COAL.

No outcrop that could be certainly recognized as the Mingo coal was seen on Stony Fork or its branches. At several places evidence of a coal having been faced at this horizon was found, but when visited all of the facings had fallen in, suggesting that the coal had not proved of workable thickness. On Bean Fork Branch this coal may be represented by 11 inches of coal with 5 inches of cannel shale 3 inches above, which Mr. Crandall gives in his section on Bean Fork Branch (301), or it may be represented by the 26 inches of coal 100 feet higher (300). On Little Clear Creek a coal at what was thought to be the horizon of the Mingo coal was reported; being a low-grade cannel, its thickness was not obtained. On Clear Creek Mr. Elliott states that this seam has a thickness of 47½ inches with a 1-inch parting 14½ inches from the top. He gives 46 inches as the average thickness of the coal as shown by three measurements. The Ramsey coal reported on Bear Creek by Mr. Fitzhugh may be the same coal. He gives its thickness as 30 inches. On Bean Fork Branch the coal at this horizon was reported to be 5 feet thick, and at one place appeared to have been opened and worked, but the opening was closed when examined and the report could not be verified. A sample of the Mason coal, representing the entire thickness of the seam, was sent to Mr. Hislop, of Paisley, Scotland, who describes it as follows:

"The coal is black, of considerable luster and brown streak, while in texture it is irregular and resinoid, containing some deposits of charcoal; cross fractures, angular, highly crystalline, and pure in composition, moderately cohesive and compact; on the fire it intumesces and agglomerates; color of ash, brown; thickness of seam, 50 inches, and of very uniform density; mean specific gravity, 1,225 (water, 1,000); weight of one cubic foot, 76.56 pounds."

Chemical analysis of coal on Bear Creek.

	Per cent.
Moisture	4.35
Volatile combustible matter	33.01
Fixed carbon	61.44
Sulphur	.45
Ash	.75

Mr. Hislop reports that this coal showed the smallest amount of ash and sulphur he had ever obtained in a bituminous coal. On the whole, therefore, this coal may be considered workable in a limited area on Clear Creek side, but elsewhere its workability must be considered doubtful unless further exploration shall show the coal to be better and thicker than it is at present known on the Little Clear Creek and Stony Fork side.

Below the Mingo coal several coals of nearly workable thickness have been opened. Just below the mouth of Coal Branch a coal opened immediately under the Fork Ridge sandstone shows a thickness of only 21 inches, and is separated by 3 feet of shale from the sandstone above. At the mouth of Hignite Creek the coal has a thickness of 29½ inches, and a 1½-inch parting 10 inches from the bottom. This immediately underlies a sandstone. A short distance farther up Stony Fork the same coal shows a thickness of only 27 inches with a 2-inch parting 8 inches from the bottom. On Little Clear Creek what is sometimes called the "Miracle" coal was reported at one place to show a thickness of 40 inches with 3 to 4 inches of clay parting near the top. At another point, supposedly the same coal was reported as 30 inches thick, but only 12 inches were seen. It here has from 2 to 10 inches of clay over it with 5+ feet of sandstone above. On the whole it may be said that as far as found no workable coals exist between the Mingo and the Chenoa cannel.

SANDSTONE PARTING COAL.

Mr. Fitzhugh reports the Sandstone Parting coal (Buckeye Spring) as showing on Bear Creek (417) 38 inches of coal with a 1-inch bench of soft coal 4 inches from the top. Mr. Crandall reports this coal as 2 feet 7 inches thick on Bear Creek (395). On Little Clear Creek this coal has a total thickness of 36½ inches (372). The sandstone parting here is 2 inches thick and 26 inches from the top. Below it are 2½ inches of cannel shale. The roof is a gray shale. The parting here ranges from a sandy or gritty shale to a sandstone. On Polk Hollow Mr. Fitzhugh reports this coal as 36 inches thick with a 3-inch shale parting 24 inches from the top. In the section of the coals at the head of Little Clear Creek Mr. Crandall reports this coal as 7 inches thick (334). On Bean Fork Branch Mr. Crandall reports this coal as 44 inches thick (460). The sandstone parting here is from 1 to 3 inches thick and comes 30 inches from the top; below it is 6 inches of shale. The section here, as will be seen, very closely resembles that on Little Clear Creek. In his sections of the coals on Bean Fork Branch Mr. Crandall makes this coal 45 inches thick with a 7-inch shale parting 16 inches from the top, and with a 2-inch sandstone parting 9 inches from the bottom (299). Messrs. McCreath and d'Invilliers give a section of this coal as measured by them on Hignite Creek (251) which shows a total of 50 inches of coal, a 2-inch parting 14 inches from the top, and 1 inch of sandstone 11 inches from the bottom. Two inches of bone coal immediately overlie the top bench. From these sections it will be seen that this coal presents a thickness of usually 3 feet or over, but that includes generally some shale and from 1 to 3 inches of sandstone. If the sandstone here, as in the Bennett Fork district, tends to stick to the coal and render the mining of the coal difficult, it is probable that this bed will be put in the class of non-workable coals. The thickest single bench ranges from about 1½ to 2½ feet, and is too thin to work by itself, so that while this coal will have a large area it will not be classed with the workable coals.

COALS OF CATRON FORMATION.

In the Log Mountains the Catron formation extends from the bottom of the Lower Hignite coal to the bottom of the Poplar Lick coal. In this region it appears to contain six coals, of which only two are workable, the Poplar Lick coal, at the bottom of the formation, and the coal which is correlated with the Klondike coal, and which in this district is a hundred feet or a little more above the Poplar Lick coal. On Bean Fork Branch, 170 feet above the Poplar Lick coal, is a coal which is thought to be too high to be the Klondike coal, and which shows the following (293): Coal, 16 inches; clay, 1 inch; coal, 1 inch; clay, 5 inches; coal, 12 inches; clay, 2 inches. On Bear Creek (388) a 26-inch coal is reported by Mr. Crandall at about the same elevation above the Poplar Lick coal. Mr. Fitzhugh reports a coal on Little Clear Creek, 170 feet above the Poplar Lick, that there shows a main bench of 32 inches with 3 inches of coal 10 inches above. These sections would all appear to be on the same coal, but only in the last section is it more than a little over the minimum workable thickness. It is thought that a workable coal can not be counted upon at this horizon.

POPLAR LICK COAL.

This coal has long been considered, and rightly, the principal coal of this district. The sections given on Pl. XIV give a good idea of this coal. They occur at intervals along its outcrop. Though most of these sections were not measured by us, enough of them were measured to indicate that the others are reliable and to lead us to accept them without question. A large number of these sections were kindly furnished by Mr. Thomas Cairns, general manager for the Louisville Property Company. These were obtained in the course of a careful instrumental survey along the outcrop of this coal. The location of the different facings is accurately shown on the map. Beginning, as before, on Bear Creek (401), the coal shows a total thickness of 54 inches with a 3-inch parting 17 inches from the top. On the east side of Bear Creek, directly opposite the last opening (403), the coal shows the same total thickness and the same thickness in the upper bench, but has a 5½-inch parting. On Cany Fork (404) the coal has a total thickness of 46 inches with an 8-inch parting 16 inches from the top. This is one of the poorest sections of this coal obtained. On Major Branch of Clear Creek east of the head the coal shows a total thickness of 69 inches with a 12-inch parting 20 inches from the top. Mr. Crandall gives a section on Major Branch showing the coal 66 inches thick, with a 13-inch parting 18 inches from the top (340). Right at Webb Gap, at the head of Ben Fork of Little Clear, the coal is 63 inches thick with an 8-inch parting 19 inches from the top. At the head of Ben Fork (339) the coal has a thickness of 72 inches with a 15-inch parting 19 inches from the top. A little farther to the east, still on Ben Fork (338), it shows 46 inches of coal without a parting. Along Little Clear Creek (337) the coal has a total thickness of 46½ inches with a 2½-inch parting 16 inches from the top. Near the head of Little Clear, but on the east side, it shows 51 inches of coal, and here the 2-inch parting is 18 inches from the top. Nearer the head of Little Clear (335) the coal is only 41 inches thick with a 2-inch parting 11 inches from the top. Farther downstream and on the west side the coal has thickened to 71 inches with a 3-inch parting 3 feet from the bottom. Still farther downstream along the outcrop (342) the coal is 58 inches thick and without partings. Mr. Fitzhugh states that this coal in Polk Hollow (352) has a thickness of 4 feet with a 6-inch shale parting 1 foot from the bottom. At another point 180 feet above the valley, on Moses Lake Hollow, he reports this coal as 39 inches thick with a 2-inch parting 13 inches from the top. Mr. Crandall reports this coal near Mart Heads on Little Clear Creek (343) as showing 63 inches of coal with a 2-inch parting 31 inches from the bottom, and 5 inches of shale parting and coal 14 inches higher. Above this parting for 3½ inches the coal is cannel. The section measured by us on the William K. Evans farm (368) showed 71 inches of coal with a 4-inch bench of bone 18 inches from the top and a 2-inch parting of bone 14 inches lower. This resembles quite strongly the section given by Mr. Crandall, but is given because of some differences. On Bean Fork Branch Mr. Crandall reports this coal as 54½ inches thick with a 2-inch parting 19 inches from the bottom, a 1½-inch parting 7 inches from the top, and a 5-inch parting 2 inches lower down (305). In his columnar section on Bean Fork Branch he reports this coal (296) as showing a total of 49 inches with 2 inches of shale 7 inches from the top, another 2-inch parting 4 inches lower, a 4-inch parting of clay 12 inches from the bottom, and another 2-inch parting of shale 3 inches higher. On Cow Branch he reports this coal as 31 inches thick with a 2-inch clay parting (306). On Lick Fork this coal showed 43 inches thick with a 3-inch clay parting near the top. On Hignite Creek two sections of this coal were measured; at the first (268) it showed 46 inches thick without parting; at the second (266) it showed an upper bench of 18 inches, separated by 18 inches of clay from a lower bench 42 inches thick. This section was measured in a stream bed and may not be entirely accurate. The facing near this had fallen in. Mr. Cairns reports this coal on this creek (278) as showing an upper bench of 29 inches, of which the upper 14 inches are cannel, and another bench 19 inches below and 34 inches thick, with a 2-inch clay parting 13 inches from the bottom. On Rockhouse, or Coal Branch, we obtained two measurements in 1902 in addition to a measurement at the Ralston mine in 1903. The first measurement obtained by Mr. Cairns on the east side of the creek (243) is reported to have shown 78 inches as a total thickness of the seam, but the coal appeared in three benches, an upper bench of 19 inches separated by 7 inches of parting from a middle 22-inch bench, and that in turn by 18 inches of parting from a bottom 12-inch bench. A under the whole of this district within its line of outcrop. It is of course possible that the facings measured and the sections reported are not representative, but from what was seen it has seemed certain that this bed will yield a large amount of workable coal. Mr. Hislop, of Paisley, Scotland, who examined a sample of the entire seam, describes this coal as follows:

"The coal is black, possesses considerable luster and brown streak; fracture rather irregular, partly defined by thin deposits of charcoal; cross fracture, angular, partly inclined to resinoid, and crystalline, and in part merging into a semicannel coal with slight deposits of calcic carbonate and ferric bisulphide in the natural partings; moderately compact and cohesive; on the fire it intumesces and agglomerates; color of ash, brown; thickness of seam, 52 inches, and of very uniform density; the mean specific gravity being 1,237 (water 1,000); weight of 1 cubic foot, 77.31 pounds."

Chemical analysis.

	Per cent.
Water	4.46
Volatile combustible matter	33.57
Fixed carbon	60.12
Ash	1.43
Sulphur	.52

The following analyses by Dr. Robert Peter are reported by Mr. Crandall:

Constituent.	A.	B.	C.	D.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	1.00	1.20	1.80	....
Volatile combustible matter	34.40	35.60	33.00	1.03
Fixed carbon	59.40	58.20	60.10	90.97
Ash	4.60	5.00	5.10	8.00
Sulphur	.682	.408	.658	.693

A. Little Clear Creek (348).
B. John Evans (344), 1 mile above A.
C. Bear Creek (406).
D. Coke made from the sample obtained on Bear Creek, a test having been made at the Pineville ovens.

According to these analyses this coal shows a remarkably low percentage of moisture, an average percentage of sulphur, a fair percentage of ash, and a little over the average percentage of fixed carbon. In comparing these analyses, however, with those obtained by us in 1902 and 1903 to the east of Middlesboro, it must be remembered that samples were taken of the whole seam, except of such partings as would naturally be rejected, and placed at once in glass jars which allowed no evaporation of the water. In these cases it is probable that the same precautions were not taken to prevent evaporation; it is more than likely that the analyses given above, and the most of those given in this and the preceding district, were made from air-dried samples. Considering the quality and favorable section of this coal, as well as the large area underlain by it, it is evident that this coal will yield a large value, probably more than that of any other seam in this district.

the sections the whole coal appears to have either nearly pinched out or to have so far split up as not to be recognized as the benches of a single coal. In any case, wherever seen, it occurs in several benches too much separated by partings, as a rule, to be workable in the same mine. On Bear Creek Mr. Crandall reports this coal (411) as showing three benches—an upper bench 22 inches thick, separated by 15 inches of shale from the main or middle bench, which is 42 inches thick, while the bottom bench of 4 inches is separated from the main bench by 10 inches of shale and coal.

Mr. G. D. Fitzhugh gives the following section of the Upper Hignite coal (420) on Bear Creek, where it has a shale roof:

	Inches.
Coal	27
Shale and clay	30
Coal	6
Shale and clay	9
Coal	19
Clay	½
Coal	9
"Mother of coal"	2
Coal	10
Shale	4
Coal	6

On Cany Fork of Clear Creek Mr. Crandall reports the following section (412):

	Inches.
Shaly sandstone roof, slaty shale	6
Coal	14
Clay	½
Coal	9½
Bituminous shale	5½
Coal	26
Clay	½
Coal	2½
Clay and shale	15

This section gives a total of 73½ inches, of which 4 feet 4 inches are coal. On Hignite Creek we measured the following section, poorly exposed in the stream bed on rather a long slope, and therefore our figures are not as reliable as might be wished. As nearly as could be measured the section gave two upper benches of 12 inches each, separated by 6 inches of clay, then a parting of 12 inches, then a lower main bench of 32 inches. Six inches below this main bench was a 2-inch bench of coal. Above the coal is 5 feet of clay shale with 10 feet or more of massive sandstone above. The floor is clay. Mr. Crandall gives a section on the same creek, probably obtained from a better exposure, which gave as follows (280): An upper bench of 32 inches under shale roof, with a 2-inch parting of shale 18 inches from the top; this is separated by 11 inches of shale from a 36-inch bench; 20 inches below the last comes an 11½-inch bench, with 2½ inches of clay 3 inches from the bottom. The total section here is over 9 feet thick with over 6 feet of coal, but so split up that it is barely, if at all, workable. In Mr. Crandall's sections of the coals at the head of Little Clear Creek, he has indicated a coal of which the thickness is not given (probably very thin), 30 feet above the Lower partings, only the lower 34-inch bench would be considered as workable, and on account of its elevation and the fact that it is not found at least showing anything like this thickness anywhere else we are led to class it among the non-workable coals. Three hundred and forty feet above the Hignite coal the following section on Bean Fork Branch may be of the same coal as the last; it shows coal and clay, 8 inches; coal, 6 inches; clay, 17 inches; clay and coal, 7 inches; cannel shale, 3 inches (285).

On Bear Creek a 3-foot coal, locally known as the Copperas Lick coal (384), is found about 115 feet above the Lower Hignite coal. Mr. G. D. Fitzhugh, in a report to the Log Mountain Coal, Coke, and Timber Company, reports a 30-inch coal 70 feet above the Lower Hignite (355). This would appear to be too high above the Lower Hignite to be the Upper Hignite.

COALS OF BRYSON FORMATION.

On Bear Creek one coal (376) in this formation gives a thickness of 1 foot 11 inches. This was the only measurement obtained of the coal in this formation, and considering that the formation occupies only a very limited area on the summit of the mountains it may be considered as containing no workable coal.

SUMMARY.

The facts concerning the Stony Fork-Clear Creek district are summarized below:

Summary of coals of Stony Fork-Clear Creek district.

Number of coal beds found	40+
Total thickness of coals . . . feet	40+
Number of coal beds of workable thickness (2+ feet)	9+
Number of coals worked at present	1
Average thickness of principal workable coals . . . feet	4+
Approximate amount of workable coal . . . tons	90,000,000

	Hignite.	Poplar Lick.	Other coals.
Approximate elevation . . . feet above tide	2,300	2,000	. . . .
Thickness:			
Greatest . . . feet	9+	$8\frac{5}{12}$	7+
Average . . . do	$3\frac{1}{3}$+	$4\frac{1}{2}$+	. . . .
Least . . . do	0	$3\frac{5}{12}$	. . . .
Average thickness of workable coal . . . do	$3\frac{1}{3}$	4	$3\frac{1}{3}$
Number of measurements	13	30+	20+
Area of seam . . . acres	5,000	10,800	5,000
Available coal per acre . . . tons	4,000	5,000	4,000
Coal available in district . . . do	20,000,000	50,000,000	20,000,000

STRUCTURE.

The general structure of this district is that of a syncline whose axis runs in a general way N. 60° E., a little southeast of the crest of Log Mountains. Starting from the head of Big Creek of Clear Fork of Cumberland River, the axis crosses the head of Copperas Fork and the head of Stony Fork in this district, it then probably swings south and crosses the heads of Coal Branch, Hignite, Little Clear, Puncheon, and Laurel branches of Little Clear, and Little Clear at the mouth of Ben Fork. As the Louisville Property Company supplied us with a copy of an instrumental survey, based on accurate levels on the Poplar Lick coal, we are able to present a contoured map of a large part of this district. Where the contour lines are dotted they are purely conjectural. On the Clear Creek side the dip is steeper north of the outcrop of the Poplar Lick coal than within the northern limits of that outcrop, as the strata rise more and more rapidly to the upturning in Pine Mountain. For the details of the structure, it is believed the contours are self explanatory. It gives a good idea of the variations from simple monoclinal slopes such as we must necessarily assume probably exist all over the field.

YELLOW CREEK DISTRICT.

GEOGRAPHY.

The dominant feature of this district is the valley of Yellow Creek. Attention has previously been called to some features of the physiographic history which indicate that the general lowness of the region is due to the erosion by the pre-Cumberland River in this basin before its headwaters had been cut off by the southward-flowing streams common in the Great Valley. The present drainage presents many suggestions of greater age than is found in most parts of this basin, notably in the low gaps which have been cut in the divides. This is probably due not to greater age but to the fact that as a result of the nearness of the main line of drainage the greater part of the erosion of the rocks in this district occurred early in recent history. Through such gaps the Louisville and Nashville Railroad gains access to and egress from Cannon Creek Valley. Just west of Moore Knob such a gap is crossed by the State road, and there are many others. It has been suggested that the gap east of Moore Knob may have been at one time in the line of drainage of Yellow Creek. Under the heading "Physiography," was discussed a recent change of drainage near the mouth of Clear Fork of Yellow Creek, and the possibility of there soon being another somewhat similar cut from Yellow Creek into the drainage of Clear Fork, a short distance above the mouth of Clear Fork. At the mouth of Sugar Run the topography suggests that the run formerly emptied into Clear Fork a little above the present mouth, but that it was tapped by a branch of Clear Fork at the position of the present mouth. These low gaps greatly facilitate transportation in this district.

Rocky Face, Cumberland, and Pine mountains, as well as Cumberland Gap, have all been sufficiently described and figured and do not need further description here. The district is crossed by the Cumberland Valley branch of the Louisville and Nashville Railroad. It is entered at Cumberland Gap by the Southern Railway, and surveys have been made for the extension of the latter railroad down Yellow Creek to Cumberland River.

STRATIGRAPHY.

The rocks found in this district are confined to the Lee, Hance, and Mingo formations. The higher formations have been cut out by the erosion already mentioned, which reduce the hills in this region to an elevation in the main of less than 2,000 feet. The Lee formation occurs on Cumberland and Pine mountains and is brought up over a large area by the Rocky Face fault. The Mingo formation occupies a very limited area in this district, occurring only in the extreme hilltops on the eastern edge, though on the west it is found on the mountain tops for several hundred feet from their summits. Even in the latter case the area within the outcrop is very limited. The larger part of the slopes, therefore, are occupied by the Hance formation. The belt of faulting described under the heading "Structure" (p. 47) occupies a large percentage of this district, and not alone in the main Rocky Face fault, but usually for some little distance either side of that the rocks are so disturbed as to make it difficult to trace any given rock layer or coal or to correlate coal beds when found. The low relief in this district, as is usually the case, is accompanied by lack of outcrops, so that on the whole our knowledge of the stratigraphy and coals of this district is limited. Again, the fact that in this district the principal formation outcropping is the Hance formation, which in the Log Mountains carries little workable coal, has discouraged exploration, and as a result at most points at which coal was seen the exposures were not of such a nature that the coal could be measured or examined. The Yellow Creek sandstone makes rather notable bluffs along all of the lower course of Yellow Creek, and along the north side of Cannon Creek for a short distance above its mouth.

COALS.

AREAL DISTRIBUTION.

On account of the conditions under which the coals of this district occur and which have been described, it will be convenient to discuss the coals in the main, not so much by beds as by areas. Between Clear Creek, Cannon Creek, and Yellow Creek at most of the points at which coal was seen there were only blooms. Datum points 465 to 468 on Clear Creek are all of this character. Coals at 469 and 470 come between the Naese sandstone and the Yellow Creek sandstone; 469 showed in poor exposure two coals, each 18 to 20 inches thick and 8 feet apart. At 470, 60 feet lower but apparently close above the Naese sandstone, the coal was reported as from 24 to 30 inches thick. At 467, supposed to be in the same horizon as the last, the coal was reported as 20 inches thick. At both of these places the coal is overlain by a fine dark-blue shale. The Yellow Creek sandstone makes bluffs of some prominence above these along Clear Creek and for a short distance up Little Clear Creek. At 356, on Little Clear Creek near the mouth of Bull Branch, is a coal bloom immediately over what was taken to be the Cawood sandstone. Its position, therefore, corresponds with the Turner coal of the Bennett Fork district or the Puckett Creek coal to the east. At 357

the coal shows a thickness of from 31 to 32 inches, and appears bright and good. Above the coal is 60 feet of sandstone separated from the coal by a 15-inch parting of clay. The coal here is 310 feet (bar.) above Little Clear Creek and would seem to correspond in stratigraphic position with coal No. 30 in the columnar section of Bennett Fork, as given on Pl. XI. Near Jerry Gap (464) coal is reported 32 inches thick at an elevation of about 1,890 feet. This is thought to lie at the same horizon as the last. No trace of coal was found in either Clear or Little Clear creeks in this district at the horizon at which it was estimated the Bennett Fork or Hance coal should lie. Where the State road meets Clear Creek, coals 461 and 462 showed, respectively, a layer 4 inches thick, and a coal bloom. All the coals seen on the east side of Moore Knob Ridge gave only blooms. These all lie low in the Hance formation. On Little Cannon Creek (463) is a coal bloom which was estimated to occupy the position of the Cranes Creek coal of the Hance district. Judging from the condition of the rocks seen in outcrop in Moore Knob Ridge, no workable coal need be looked for in that hill.

The hills between the railroad and the portion of Yellow Creek below the mouth of Cannon Creek probably contain no workable coal. Near the top of the hill, on the Hiram Hoskins place, McCreath and d'Invilliers report a 3-foot coal with a shale roof and a half-inch parting of shale 2 feet from the top. They give the following analysis of this coal:

Analysis of Hoskins coal, Yellow Creek.

	Per cent.
Water	1.240
Volatile matter	40.785
Fixed carbon	51.841
Sulphur	2.289
Ash	3.845
Color of ash, red.	

This is described as having been opened on the west side of Yellow Creek, a short distance above the mouth of Williams Branch, about 360 feet vertically above the level of the creek. The coal occurs in yellow ferriferous shales immediately above a massive sandstone rock. Though the coal was not seen by us, probably the same sandstone which is thought to be the Cawood was noted in cliffs near the top of the hill. If this view is correct, this coal is the representative of the Turner coal of the Bennett Fork district or the Puckett Creek coal, farther to the east. McCreath and d'Invilliers described the coal as "bright and firm and to have a large area through the high knob between Yellow Creek and the river." According to the topographic map, the top of this hill is about 125 feet above the coal and in the form of a knob, and the coal would underlie but a very few acres. It is possible that the Cranes Creek coal, which lies 100 feet or more lower, may be found in this hill, and if so it would yield a small quantity of workable coal.

Of the portion of the area just studied west of the State road little can be said. This contains the horizons of the Bennett Fork coal and of the Mingo coal, though the latter would occupy only a very limited area. It is possible that both of these coals, or at least the lower of them, may in the future be found in this part of the district and may yield some workable coal. One or two exposures on what was taken to be the Turner coal seem to indicate that that coal was too thin to be of any value. Rocky Face Mountain contains no workable coal unless one of the Lee coals found in Cumberland Gap should occur here. In that case it would lie in a more or less nearly perpendicular position and could not be considered minable.

In the Sawmill Ridge hills between Cannon Creek and Yellow Creek the indications are more favorable for the existence of workable coals. At 451 on Cannon Creek a coal 2 feet thick was seen and was estimated to lie at the horizon of the Turner and Puckett coals. At 452 just above this and near the top of the hill the coal was reported as 4½ feet thick. It appeared to occur in the stratigraphic position of the Mingo coal. From its position in the hill it would occupy but a small area, though probably large enough to pay for mining. Messrs. McCreath and d'Invilliers report a coal as having been opened upon the F. Barner place, described as close to the State road and about a mile south from the Cannon Creek divide and a short distance west of Yellow Creek. It is correlated by them as at the same horizon as the Hoskins coal. The coal here was formerly mined considerably for local use, especially for smithing. It is described as 2 feet 10 inches thick, with a small black slate parting 2 inches from the top and a band of iron pyrites about 16 inches from the top. The State reports contain the following analyses of this coal. The first is of the whole bed, including the parting and pyrite, and the second is of the coal without these impurities.

Analyses of Barner coal on Cannon Creek (Peter).

Constituent.	A.	B.
	Per cent.	*Per cent.*
Moisture	0.86	0.86
Volatile combustible matter	35.60	36.04
Fixed carbon	57.88	59.20
Ash (color, bright lilac gray)	5.66	3.90
Sulphur	2.455	2.032
Specific gravity	1.281	1.270

The coke from this coal was light and spongy. The analysis of the coke showed as follows:

Coke from Barner coal on Cannon Creek (Peter).

	Per cent.
Moisture	0.06
Volatile combustible matter	.60
Fixed carbon	93.34
Ash	6.00
Sulphur	1.335

coal. All told there is about 3½ feet of coal here, but so badly split up as to be nonworkable.

On the north end of Dark Ridge we find the only commercial mine worked in this district in 1902 and 1903. At the Excelsior mine (458) the coal worked is considered to be the Mingo coal. The principal bench of coal runs from about 2½ to 3 feet in thickness. Above it is from 4 to 18 inches of shale and above that occasionally a thin strip of coal that reaches a thickness of 4 inches. Nine feet higher is an 18-inch bench of coal. Below the main bench the coal has a parting usually running from 3 to 10 inches thick, averaging about 8 inches, though in the first left entry this parting thickens up to 3 feet. Below the parting is 18 inches of coal. Where measured near the furnace this parting showed 10 inches of clay, 4 inches of coal, and 8 inches of clay. A few feet below the entrance to the mine and to the south is an outcrop of massive sandstone considered to be the Fork Ridge sandstone. The coal here dips slightly to the east, and as far as entered the main entry had been cut 350 yards S. 66° E. A coal that is supposed to be this seam was reported by Messrs. McCreath and d'Invilliers in this mountain at an elevation of 550 feet above the creek. Their section, however, differs considerably from that obtained in the mine, as it showed a total of 4 feet 9½ inches of coal with a sandstone roof. Their section gives 1 foot of coal at the top, 1 inch of shale, 11 inches of coal, 7 inches of clay shale, 2 inches of coal, 1 inch of clay, and 1 foot 11½ inches of coal. A barometric measurement in 1902 showed the mine to be 610 feet above Yellow Creek. In view of the possibility of differences in the reading of the barometer, or of the dip of the coal, if these measurements were made any considerable distance apart these differences in elevation above the creek need not necessarily mean that the two coals are not at the same horizon. They give the following analysis of this coal:

Analysis of coal on Dark Mountain.

	Per cent.
Moisture	2.412
Volatile combustible matter	37.148
Fixed carbon	54.677
Sulphur	1.013
Ash (color, dark red)	4.750

The large parting in this coal necessarily interferes more or less with its workability. It is possible that the Hance, Bennett Fork, or Turner coals may yet be found in this mountain, and prove of workable thickness. In any case the area of workable coal is apt to be limited, as the Rocky Face fault, or (as it appears here) anticline, has disturbed the rocks in the eastern half of the mountain. Whether this disturbance continues through the whole of the eastern part of the mountain or whether it dies out a short distance south of the southern end of Rocky Face Mountain was not learned.

On the ridges between Yellow and Williams creeks it is possible to again consider the individual coals. There appear to be four coals in these ridges, all of which may prove locally workable, and one of which gives promise of being persistently workable. Unfortunately, however, the Hance coal lies near the top of the mountain, so that its area will be quite limited.

COALS IN THE LEE FORMATION.

On the road from Middlesboro to Cumberland Gap two coals in the Lee formation have been mined. The first of these met in going up the road outcrops at several points and has about the same strike as the coal mined on the road. One of these points is just outside the northern end of the railroad tunnel under the gap. This coal, therefore, we have called the Tunnel coal. The upper coal (lower stratigraphically) has been opened at several points only a few rods below the gap, and will be called the Cumberland Gap coal. The Tunnel coal was being mined in 1902 a little to the east of the north end of the tunnel, where its thickness was from 22 to 57 inches, averaging between 40 and 42 inches. At this point it dips N. 68° W. at an angle of 29° or 30°. Part of the coal blocks out well, while part of it is softer and breaks down nearly to nut size. The coal is mined by shooting. The roof is of drab-gray shale and not very firm. Below the coal are 4 feet of fire clay. In 1903 this mine had been abandoned; it was reported that the coal was followed until it ran down to 8 inches, and then an entry was continued into it until it had risen to 17 inches, when further mining was discontinued. Over the coal are 14 feet of shale and 15 feet of massive sandstone, with an equal amount of less massive sandstone above. On account of the dip the usual method of mining rooms on dipping faces was followed. It is reported that at the old mine on the Cumberland Gap road the coal was 4 feet thick, blocked out well, being hard and but little crushed. As at the other mine, it was mined with powder, though it could be mined without. Part of the roof needed no timbering. The Cumberland Gap coal, which was being mined actively, though on a small scale, in 1903 showed at different openings a thickness of from 4 to 6 feet. A typical section (499) would show a massive conglomerate sandstone roof, then clay, 0 to 2 inches; soft coal, 5 inches; coal, 20 inches; brown coal, 5 inches; bright coal, 33 inches, and a light-gray fire clay below. At this point the coal dips N. 65° W. at an angle of 48°. It was reported that this coal was crossed by the railroad tunnel, where it showed a thickness of 6 feet. One-fourth of a mile or more from Cumberland Gap on the road to Harlan (500), the same coal has been mined close to the fault line. It showed a thickness of 44 inches and a dip of 52° in the direction of N. 78° W. It is very irregular. In places the roof is a sandstone, and near the bottom of this entry there is from 5 to 6 feet of soft clay shale between the sandstone and coal. This opening lies N. 10° E. from the opening previously described (499). Comparing the position with reference to the first opening and the strike of the coal at the several openings close by the gap, it is evident that the coal bed has been strongly twisted in a horizontal plane so that the strike has been changed from N. 65° W. to N. 12° W.

CRANES CREEK COAL.

The type locality for this coal was on the J. Cal Robbins place (492), on the right-hand fork of Sugar Hollow Branch of Cranes Creek. The coal here shows a solid face of 46 inches, with a drab clay shale roof; some hard, bony streaks show locally in the coal. The faces show markedly and run S. 50° W. The hill rises about 250 feet above the coal. At another place on the Robbins farm lower down Cranes Creek and on the other side this coal showed 39½ inches without partings. According to the barometer readings it was there 50 feet higher than at the first-mentioned opening (491). Across the ridge from the first opening mentioned (492) this coal has been mined on the James Barnett place (489), whence it was hauled over Cumberland Gap into Virginia. The coal here showed 40 inches without parting, with a drab clay shale roof 14+ feet thick. A little farther up Cranes Creek this coal in 2 openings shows solid faces of 25 inches at 482 and 32 inches at 483, the latter point being north of Cranes Creek. At the former place the coal has a sandstone floor and a sandy shale roof; at the latter it has a dark hard fire-clay floor and a sandy shale roof. Of the two analyses of this coal the first is by McCreath from a sample at the type locality obtained in 1902, and the second is by Peter from a sample at the James Barnett mine, obtained by Mr. R. C. B. Thruston.

Analyses of Cranes Creek coal on Cranes Creek and Clear Fork.

Constituent.	By McCreath.	By Peter.
	Per cent.	*Per cent.*
Moisture	1.470	0.80
Volatile combustible matter	37.610	33.94
Fixed carbon	52.763	58.86
Sulphur	1.347	1.398
Ash	6.810	6.40

The coke from the coal whose analysis is given in the first column is fair but somewhat granular, that from coal whose composition is given in the second column is described as light and spongy. The color of the ash in the second case is light-purple gray. As is usual with analyses by Peter, the sample was an air-dried coal. Both of these analyses seem to indicate that this coal is high in sulphur, and above the average in percentage of ash. On account of its low position in the hills and the fact that at every point where it was seen it showed a solid body without partings, it is possible that it will yield considerable workable coal. Its thickness is not all that could be desired, and over part of the district it will probably prove too thin to be workable, especially if the analyses at other points do not show much better than at the two given.

PUCKETT COAL.

Near the head of the middle prong of the right-hand fork of Williams Branch this coal was seen in two benches, the upper of which was 49½ inches thick, including 3 inches of black shale, 6 inches from the bottom, and 1½ inches of black shale 15 inches from the top. Between the two benches are, first, 18 inches of dark-drab fire clay and 6 inches of black shale. The lower bench, which was only partly exposed, was reported as 2 feet thick. Where seen this coal was 400 feet above the main forks of the right-hand branch and 20 feet above the adjacent drainage. Messrs. McCreath and d'Invilliers report a section of a coal, which would seem to be the same bed, as it gives a very similar section. Their section shows 1 foot of coal at the top, a knife-edge of slate and 2 inches of coal, 2 inches of slate, 1 foot 7 inches of coal, a knife-edge of slate, 1 inch of coal, 5 inches of splinty and bony coal, 2 inches of slate, 4 inches of coal, 1 foot 8 inches of slate, and 1 foot 6 inches of coal, the total thickness being 7 feet 1 inch. They report this opening as being on the right-hand fork of Williams Branch, a small stream flowing westward, in the creek near R. Marlor's cabin about 1¼ miles from the main creek and practically 450 feet above the level of Williams Branch. Notwithstanding the fact that this coal is thick it can not be considered workable at this point on account of the number of partings, though it may prove workable at other points should one or more of the thinner partings die out.

HANCE COALS.

These two coals were poorly exposed at the head of Turnhole Branch (472). The coal at this point lies only about 50 feet below the crest of the ridge, though to the south the ridge becomes much higher. The two coals appear to be about 9 feet apart vertically; the upper coal showed a thickness of 2 feet with a clay-shale roof; the lower coal has a shaly sandstone roof 4 feet plus thick. As far as seen it is composed of an upper bench of 15 inches, and a clay parting of 4 inches, while of the lower bench only 22 inches could be seen. On the William Denny place (475), at the head of a branch of Cranes Creek, the lower coal shows a thickness of 4 feet 8 inches. There is a lower bench of 22 inches separated by 4 inches of shale from an upper bench of 30 inches. The latter has a ½-inch parting 9 inches from the bottom and a ¼-inch parting 9 inches higher. Above it is 1 inch of bone. The roof is of sandstone. The upper coal shows in a spring above Mr. Denny's. In a spring to the east of Denny's house the lower Hance coal shows again, and, though very poorly exposed, seems to have about the same thickness. According to barometer measurements, there is a rise of about 40 feet in the coal when passing through this hill. The upper coal shows faintly about 25 feet above the spring (476). On the C. C. Wright place the coal has a total thickness of over 5 feet in practically two benches—the upper one 3 feet thick and the lower 2 feet, or a trifle under, thick, with 2½ inches of clay between. The roof is shale. A section of what is probably this coal on the J. M. Robbins place, by Messrs. McCreath and d'Invilliers, shows practically the same strata—that is, an upper bench 3 feet thick and a lower bench 2 feet thick, and 3 inches of shale between; the roof is sandstone and the floor fire clay. The faces of this coal up Denny Run lie N. 30° E. The same coal is reported to occur in Clear Fork Ridge just level with the gap at the head of Yellow Branch, and to have a thickness of about 4 feet (488). At the head of a small branch of the middle or main prong of Williams Creek, and about 90 feet barometrically above the Robbins opening, Messrs. McCreath and d'Invilliers report a coal which probably occurs at this same horizon. It is given as on the B. F. Gross place. It shows a top bench of 2 feet 9 inches, with a knife-edge of slate 11 inches from the bottom, and a 2-inch slate parting. Below that were reported, though not seen by them, 3 feet 10 inches of coal, 1 foot 6 inches of clay, and 10 inches of coal, giving a total thickness, if

HANCE DISTRICT.

GEOGRAPHY.

This district is practically included in the two ridges on each side of Hance Creek—Williams Ridge on the west and Hance Ridge on the east. Coal occurs in Laurel Hill, and is of workable thickness in Cumberland Mountain, but practically all the workable coal is confined to the two ridges mentioned, with their numerous spurs. In general this district is low, seldom rising above 2,000 feet, while the rocks exposed are low in the stratigraphic column, so that the total body of workable coal here is quite limited. The streams give easy access to all of the coal. Railroads should approach from the Cumberland River side and mining should begin on the north side and extend southeastward up the dip. The massive sandstone above the Hance coal has helped to make the ridges in the district rather broad topped, so that a much larger body of coal has been preserved than would have been the case if the ridges had been sharp crested, as they are farther east.

STRATIGRAPHY.

The rocks of this district belong almost entirely in the Hance formation. The valley bottoms are largely cut out of the Lee sandstone, and the hilltops are mainly in the Mingo formation. The stratigraphy and structure in this district are much simplified by the occurrence of four cliff-making sandstones.

LEE FORMATION.

NAESE SANDSTONE MEMBER.

The Naese sandstone has its typical exposure in this district, and forms cliffs all along the Cumberland River from Brownies Creek to Yellow Creek, where its top is just about at river level. On the north side of the river low cliffs of this sandstone appear just above the road at Campbells Ford and eastward these cliffs recur at short intervals, gradually gaining in height, until above the mouth of Hance Creek they become almost continuous to the mouth of Tanyard Branch. The Naese Cliff and the Seven Sisters shown in Pl. VIII well illustrate the character of the exposures of these sandstones in this region. Though the top of this sandstone is but little above drainage at the mouths of Hance and Williams creeks, the rise to the southeast keeps it above the level of Hance Creek for some distance above the mouth of Wolfpen Branch, and for some distance up Williams Branch. It is, of course, very prominent on the northern flank of Cumberland and Brush mountains and the southern side of Pine Mountain.

HANCE FORMATION.

YELLOW CREEK SANDSTONE MEMBER.

About 100 feet above the top of the Seven Sisters sandstone is the top of the Yellow Creek sandstone, which has its typical exposure in this district, at the mouth of Yellow Creek, on the right-hand side. This sandstone runs from 25 to 60 feet thick, and, though not so prominent a cliff maker as the Naese sandstone, bare outcrops are usually found where it is crossed by roads or streams, and fairly prominent cliffs occur with some frequency. The 60-foot cliff at the mouth of Yellow Creek extends to the mouth of Williams Branch, and is rather pronounced at one or two places up Williams Branch. It can readily be traced up Hance Creek and Pitmans Creek, where it makes occasional cliffs, usually 100 to 150 feet above the stream. It is below drainage on Brownies Creek from the end of the lower Sam Low road to the mouth of Elk Branch. From that point to above the mouth of Cubage Creek it makes almost continuous cliffs, usually within 50 to 75 feet of the stream. .

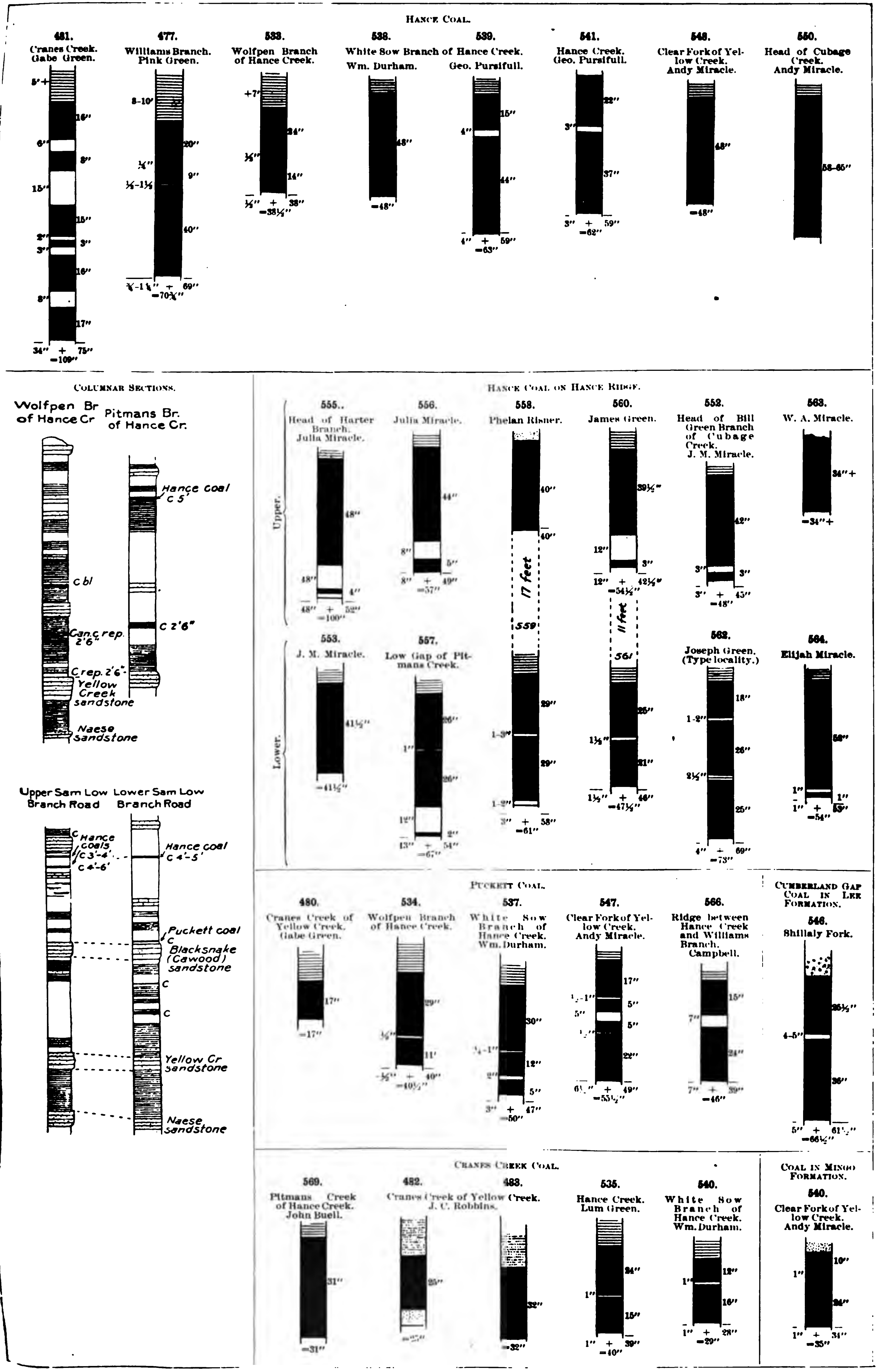
Between the Yellow Creek and Naese sandstones are shales which are usually fissile and are frequently black. At one or two horizons near the bottom of this shale are coals, usually thin, and generally cannel in character. In places these cannel coals are replaced by cannelly shale.

CAWOOD SANDSTONE MEMBER.

From 200 to 260 feet above the Yellow Creek sandstone occurs the top of the third massive sandstone. This sandstone has the same position as has been thought to be equivalent to the Cawood sandstone of the region farther east. On account of the elevation at which this sandstone occurs, it is not so noticeable from the valley roads and trails as the Yellow Creek sandstone. Along Brownies Creek it produces cliffs 200 to 300 feet above the stream that are easily seen from the road. On most of the trails or roads crossing its horizon it makes bold and often cliffy outcrops, while on the branches it tends to produce marked benches. These benches, just above the outcrop of this sandstone, are usually made more noticeable by being under cultivation, the bench frequently yielding 40 acres or more of fairly flat land. These benches are not shown on the topographic map, or it might be possible to indicate the position of the sandstone from the map. An illustration of this type of bench is seen on the Brownies Creek side of the lower Sam Low road about 300 feet above the end of the road at Brownies Creek.

Between this sandstone and the one below, the strata are composed mainly of shale. In some places they appear to be nearly all shale, but toward the top there is generally a little shaly sandstone which locally is hard and resistant. There appear to be at least three coal horizons in this space, though seldom more than one is seen in a single section. One of these coals is just above the Yellow Creek sandstone, another is 100 feet higher, and the third is 100 feet below the top of the Cawood sandstone, or 50 feet above the middle coal. It is thought that the middle coal corresponds to the Cranes Creek coal.

The top of the fourth of these sandstones is about 240 feet above the top of the Cawood sandstone. While this sandstone makes cliffs and bold outcrops, these are not very conspicuous and would attract little notice if the principal coal of this district did not occur about 40 feet below them. This sandstone is well exposed on the summit of Hance Ridge along the upper Sam Low road, and at various points along the crest a little below the road. The spur or ridge between Hance Creek and Williams Branch is too low to catch it, but it makes several small cliffs near the top of the ridge between Wolfpen Branch of Hance and Cranes creeks.



COLUMNAR AND COAL SECTIONS, HANCE DISTRICT.

Between this sandstone and the Cawood sandstone the rocks are mainly shale, but there is some hard sandstone, especially a short distance below the Hance coal. A small but variable distance below the upper sandstone are two coals which are workable and are from 10 to 40 feet apart. The upper one is about 20 feet below the upper sandstone. A third coal, workable in places, is a few feet above the Cawood sandstone. This last coal is considered to be the equivalent of the Puckett Creek coal in the Lower Puckett district.

A summary of the coals and principal sandstones of this district follows:

Condensed section of rocks of Hance district.

Stratum.	Depth.	Total depth.	Stratum.	Depth.	Total depth.
	Feet.	*Feet.*		*Feet.*	*Feet.*
Sandstone	40–20	20	Coal	?	....
Shale	20	40	Shale	50	455
Coal, Upper Hance	3	43	Coal, Cranes Creek	2⅓–3	458
Shale and sandstone	[a] 15	58	Shale	80	538
Coal, Lower Hance	4	62	Coal	¼–2	540
Shale, some sandstone	180	242	Shale	20	560
Coal, Puckett Creek	3	245	Sandstone, Yellow Creek	60	620
Shale	10–20	265	Shale, black and thin coal	60	680
Sandstone, Cawood	60–40	305	Sandstone, Naese, exposed	150	830
Shale and sandstone	100	405			

[a] 10 to 40 feet.

COALS.

Near the head of Clear Fork of Yellow Creek three coals were measured. The lowest is 4 feet 7 inches thick; the next, 177 feet above, is 4 feet thick; while the highest, 70 feet above the middle seam, is nearly 3 feet thick. In view of the distance between the coals and their relative thicknesses it seems probable that the middle seam is one of the Hance coals, and, as the upper bed is too far above it to be the Upper Hance coal, it has been considered to belong in the Mingo formation. If this view is correct this coal is the only one in the Mingo formation measured in this district. It shows 35 inches of coal with a 1-inch parting 10 inches from the top, and a sandstone roof (549). It is 310 feet above Clear Fork.

CUMBERLAND GAP COAL.

A short distance below the point where Shillaly Fork turns from a westward course to a northward course and descends to the level of Clear Fork there is an exposure of a 5-foot coal that from its position was thought to be the representative of the Cumberland Gap coal at Cumberland Gap. It is immediately overlain by the massive coarse-grained conglomerate. It shows two benches, the upper has a thickness of 25½ inches, and is separated by from 4 to 5 inches of clay from the lower, which has a thickness of 3 feet and is underlain by a brown clay floor. This seam is exposed on the east side of the creek only a few feet above the creek level.

It dips N. 80° W. at an angle of 15°. The coal shows abundant evidence of the stresses it has been under, and is badly cut up with slips and faults, and in the main appears to lie in flakes twisted in all directions. It is a bright, clean coal, though it shows a few plates of pyrites. On account of its broken-up condition and its dip it may be doubted if it can be considered as workable. What was thought to be the same coal was seen at the western end of Brush Mountain at an elevation 500 feet higher. The coal here is immediately below a bluff of coarse conglomerate. There was poorly exposed an upper bench of 2 feet of coal, then a thin parting of shale with coal below. At the foot of the bluff the contact of the coal and the conglomerate roof suggested that the weight of the cliff above had compressed or broken the coal in the vertical line of the cliff so that the coal on the outside of the cliff runs 7 inches above the level of the top of the coal under the cliff.

CRANES CREEK COAL.

Another coal of barely workable thickness is found from 100 to 170 feet below the Puckett coal. It is not certain that these coals are all at the same horizon; in places they are certainly the same as the Cranes Creek coal in its type locality. This coal is not as thick as those considered above, but tends to be solid or nearly so. On Cranes Creek in this district, as in the Yellow Creek district, it is solid, ranging from 25 to 33 inches thick (482 and 483). It is opened on the Lum Green place on Hance Creek, a little below the mouth of Wolfpen Branch and 250 feet above the creek (535). Here it shows 40 inches of coal with a 1-inch parting 24 inches from the top. The roof is a dark-drab shale. The dip here is slightly into the hill, or to the west. It was also opened on the William Durham place on White Sow Branch at an elevation of about 1,420 feet (540). It shows 29 inches of coal with a 1-inch parting 12 inches from the top. The roof is a dark-blue clay shale, and the floor a drab fire clay. On Pitmans Creek it is opened upon the Sampson Thompson place (567). There is here from 30 to 31 inches of coal with one-half inch of bone in the middle, and a shale roof. This coal is also opened on the same creek on the John Buell place (569), where the thickness is practically the same and there is a 3-inch hard band 1 foot from the bottom. The elevation here is 1,353 feet above tide, and the faces run due east. On the whole this coal averages about 31 inches in thickness, being little thicker than the lower limit of workable coal, but on account of its good quality and its low position in the hills it may prove of future value.

Only one analysis was obtained of this coal and that was of a sample from the Buell opening (569).

Analysis of Cranes Creek coal on Pitmans Creek.

	Per cent.
Moisture, as received	2.043
Moisture, ground coal	1.372
Volatile combustible matter	36.628
Fixed carbon	58.917
Sulphur	.993
Ash	2.090
Phosphorus	.002

Coke, good.

Section of Hance coals on J. L. Green farm.

No. on map.	Stratum.	Thickness.		Total thickness.	
		Ft.	*in.*	*Ft.*	*in.*
	Sandstone			10	0
	Shale, dark blue			[a]9	0
560	Coal, upper:				
	Coal	0	1		
	Clay		2		
	Coal	3	3		
				3	6
	Fire clay, drab			1	0
	Coal and black shale				3
	Shale, brown, clay			10	0
561	Coal, lower:				
	Coal	2	1		
	Clay, black		1½		
	Coal	1	9		
				3	11½
	Fire clay, dark drab			1	0
	Shale			4	0
	Sandstone, shaly			1	6+

[a] 4 to 9 feet.

The sandstone and shale above the upper coal overlap so that the thickness of the shale varies from 4 to 8 feet at points but a few feet apart. Both coals were seen at only comparatively few places. Not including the thin streak of coal from a few inches to 4 feet below, the upper coal appears to be generally a solid coal between 3 and 4 feet thick. While the lower coal may run from 3½ to 5 feet or more thick, it is usually cut by one or two partings. These are commonly thin, but an exception is found on the Gabe Green place at the head of Cranes Creek.

One of these coals was seen near the head of Hance Creek on the George Pursifull place (541). Here it has a thickness of 5 feet 2 inches, with one 3-inch parting 22 inches from the top. It is 345 feet above the creek (1,738 feet above tide, actual elevation).

At the head of Wolfpen Branch of Hance Creek one of these coals has been faced (533) and shows a thickness of 3 feet 2½ inches, with a ½-inch parting 2 feet from the top. The roof is light-brown to light-drab shale, 7 feet plus thick. The small thickness here suggests that this may be the upper bed. The coal is about 30 feet below the cliff-making sandstone and nearly 100 feet below the level of the gap between Wolfpen Branch and Cranes Creek. On the opposite side of this ridge at the head of Cranes Creek one of these coals shows an interesting development on the Gabe Green place (481). It has a total thickness of over 9 feet, of which over 6 feet are coal and almost 3 feet are partings. The coal benches beginning at the top measure as follows: 16, 8, 15, 3, 16, and 17 inches; total, 75 inches. The partings from the top down measure 6, 15, 2, 3, and 8 inches, making a total of 34 inches, or 109 inches for the whole bed. The roof is clay shale 5 feet plus thick. This appears to be at almost the same elevation as the last coal, possibly a few feet higher and but a short distance horizontally away. It does not seem probable that these openings are on the same bed. Northward toward the head of Williams Branch an excellent section of one of these coals occurs on the Pink Green farm. It shows 69 inches of coal, with only two thin partings. One is composed of one-fourth inch of soft coal 20 inches from the top; the other is composed of one-half to 1½ inches of clay 9 inches lower. The top 8 inches of the coal was weathered, but below that the coal is good and bright. An opening had been driven on the coal for a distance of 8 to 10 feet. The roof is clay shale 10 feet plus thick. The hill rises at least 170 feet above the coal.

One of the Hance coals was partly exposed on a spur running toward Cranes Creek on the J. C. Robbins place (485). The bottom bench shows 2 feet of coal. On the John Denny farm, at the gap between the head of the right-hand fork of Williams Branch and a branch of Cranes Creek, both coals occur only 8 or 10 feet apart. The upper coal (479) is 3 feet thick. A partial facing on the lower coal shows the lower bench to be 38 inches thick. Mr. Creech reports the coal here to be 100 feet higher than on the William Denny place a short distance to the west. (See pp. 117, 118.)

The Hance coals were not seen on the rest of the ridge west of Hance Creek in this district, and it may be doubted if the northern part of the ridge is quite high enough to catch them. The highest point between the left-hand fork and main fork of Williams Creek must just about reach their horizon.

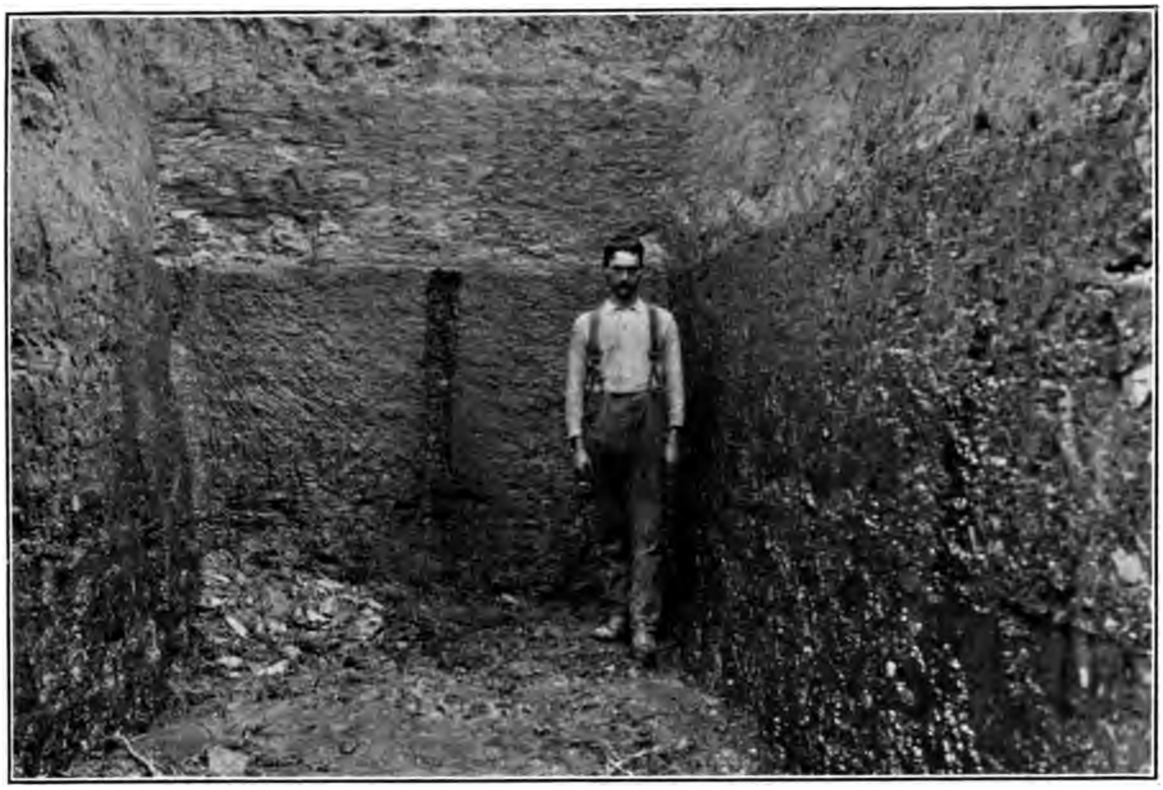
On Hance Ridge one of these coals makes an excellent showing on the Andy Miracle farm, close to and about 75 feet above the gap between Cubage Creek and Clear Fork (550). The bed, which has been drifted on a few feet, shows from 4 feet 10 inches to 5 feet 5 inches solid coal. Over it there is 8 feet of light-drab clay shale under 3 feet of sandstone. The shale shows clearly the effect of stresses, being broken and slightly folded, and it is probable that the variation in thickness of the coal is due to the same cause, as it shows irregular jointing, clay slips, etc. The coal here is very close to the line of folding, where the rocks are upturned in Brush Mountain, so that the coal at this end of the ridge may be expected to be crushed and liable to produce a large amount of fine or slack coal. The floor here is dark-drab clay. There are two openings in this same ridge between the head of Bill Green Branch of Cubage and Clear Fork. At one of these (551) the coal is reported to be 43 inches thick, without partings. At the other opening (552) the bed shows a thickness of 4 feet, with a 3-inch clay parting 3 inches from the bottom. This is a facing well driven into the hill. The roof is light-drab clay shale 6+ feet thick, and the floor is drab fire clay. The coal here Mr. Creech reports to be 3 feet higher by levels than at the head of Cubage Creek. The coal still shows some of the same disturbed condition as at the head of Cubage Creek.

Several facings have been made on the spur, between Sal and White Sow branches of Hance Creek and Clear Fork. On the Clear Fork side a facing on one of these coals (548) on the Andy Miracle place shows 4 feet of coal without partings. The roof is light-brown friable clay shale and the floor drab fire clay. It is 240 feet above Clear Fork. On the Hance Creek side of the ridge there are facings on the George Pursifull and William Durham farms. On the former (539) the coal shows a thickness of 5 feet 3 inches, with 4 inches of clay 15 inches from the top. The roof is light-brown clay shale. At the facing on the William Durham farm the coal is 4 feet thick, without partings (538). The floor is dark-drab fire clay and the roof light-drab clay shale. The coal here has an elevation of 1,778 feet above tide—practically the same as the last facing.

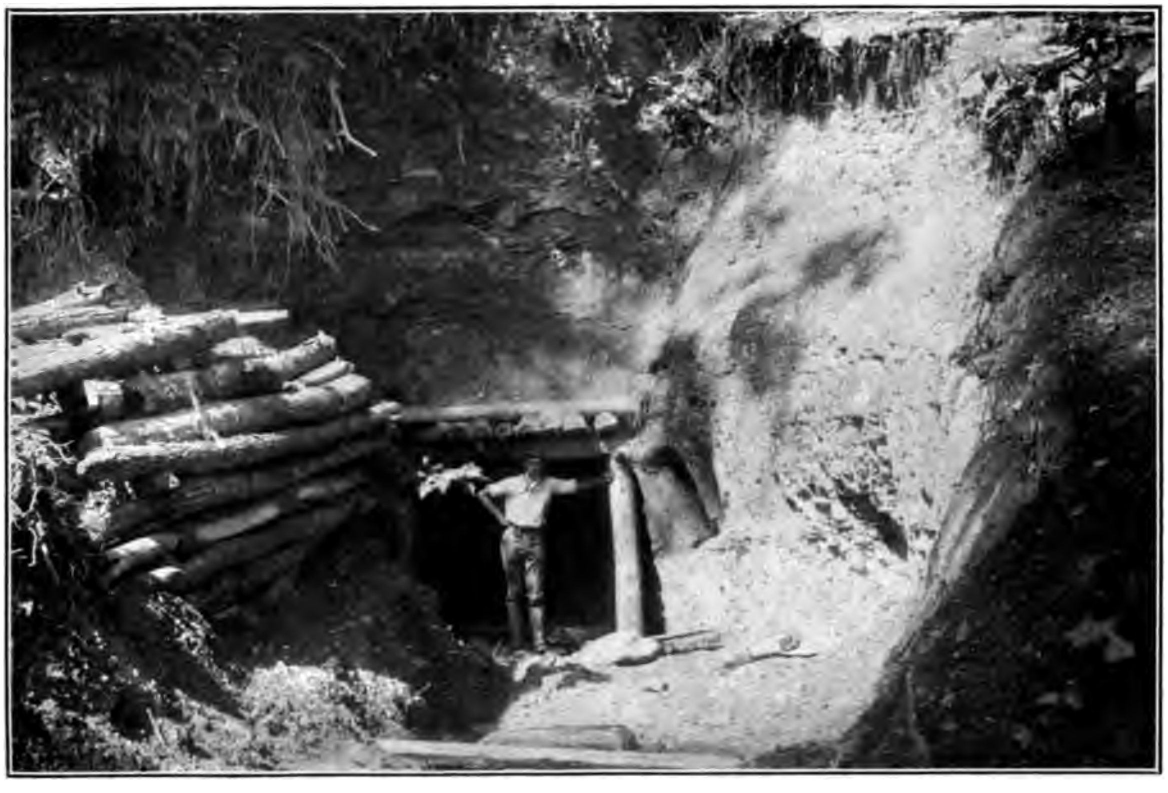
What is probably the lower coal is opened at the head of Right-hand Fork of Cubage Creek (553). It shows 41½ inches of solid coal. The floor is light-drab fire clay, the roof light-drab clay shale. About a foot above the coal occur a number of thin streaks of coal an inch or less thick. At 40 feet above occurs from 12 to 18 inches of coal under 4 feet plus of gray shaly sandstone. Halfway between is a faint smut mark suggesting a thin intermediate coal.

At the head of Harter Branch there are two openings on the Julia Miracle place. At one of these (555) the coal shows 42 inches of coal without partings. The facing had not reached solid roof. Below the coal is 4 feet of dark- to light-drab clay, with 4 inches of coal below that. About 50 feet above the coal comes the bottom of about 50 feet of light-brown shale, well exposed, suggesting that this coal is probably close to the cliff-making sandstone, which must come in the 50-foot interval just above it, and so indicating that this is the Upper Hance coal. At the other opening on this farm (556) the main bench is 44 inches thick, the 4-inch coal at the preceding opening is here 5 inches, while the 4 feet of clay at that opening is here only 8 inches. The roof is brown clay shale 7+ feet thick. At the "Low Gap of Pitmans" at the head of Pitmans Creek the two Hance coals are both seen about 25 feet apart. The lower coal is about 10 feet above the level of the gap (557), and by levels reported 58 feet below the last-mentioned Julia Miracle coal. If, as supposed, the latter is the upper coal, this gives a dip of about 25 feet between these points. The lower coal here is 4 feet 5 inches thick with 1 inch of soft coal in the center. Over the coal is 2 to 3 feet of brown clay shale overlain unconformably by 2 feet of sandstone. Below the coal is clay showing a streak of coal 1 foot down. The upper coal, 25 feet above, was only partly opened.

A short distance farther north, still at the headwaters of Pitmans Creek, both coals are well exposed on the Phelan Risner farm. They appear to be about 17 feet apart vertically. The coals give the following section:



A. HANCE COAL AT JOSEPH GREEN'S, WEST SIDE OF HANCE RIDGE.



B. ENTRANCE TO HANCE COAL MINE OF PHELAN RISNER.

Head of Pitmans Branch of Hance Creek.

Section of Hance coals at the Phelan Risner farm, Pitmans Creek (Pl. XVII).

No. on map.	Stratum.	Thickness. Ft.	Thickness. in.	Total thickness. Ft.	Total thickness. in.
	Shale and sandstone			0	0
558	Coal, upper			3	4
	Fire clay, drab			1	0
	Shale, light drab			8	0
	Shale, blue			8	0
559	Coal, lower:				
	Coal	2	5		
	Clay		[a]3		
	Coal	2	5		
				5	1
	Shale, black				2
	Clay, dark drab			2	0

[a] 1 to 3 inches.

In places thin bands of coal appear just above the lower coal, a 2-inch band is 3 inches above, and a 3-inch band occurs 10 inches higher. Just at the lower opening the coal and rocks dip N. 10° W. at an angle of from 2° to 3°. This dip is probably local. The difference in ash in the analyses of samples of this coal obtained by Mr. McCreath and by our party is probably accounted for by the fact that the clay parting was thrown out by Mr. McCreath and retained by us. The elevation of the lower coal here is 1,669 feet above tide, actual elevation.

A section has already been given at the J. L. Green facings (560 and 561). The upper part of the upper bed is somewhat splintery, and there is a thin streak of bony coal 8 inches from the top. Notwithstanding this the analysis shows a low ash. The upper coal is harder than the lower coal, though chemically they are very similar. The block structure of the coal shows unusually well here, the face slips running N. 40° E. The coals have elevations of 1,731 and 1,715 feet above tide, respectively.

On the Hance Creek side of the ridge a coal, probably the lower, has been opened on the Joseph Green place at the head of Sam Low Branch and south of the upper Sam Low Branch road. A facing on the coal here has been driven in and walled up in a rather unusual manner, but the section of coal exposed is also unusually good. (See Pl. XVII.) The section shows the whole bed to have a thickness of over 6 feet (562) with two thin partings. The upper parting, 18 inches from the top, is black clay from 1 to 2 inches thick; the lower parting, 25 inches from the bottom, is drab shale 2½ inches thick, leaving a total of 5 feet 9 inches of coal. The top of the cliff-making sandstone is here 50 feet above the top of the coal. The coal is here 1,709 feet above tide.

Beyond the upper Sam Low road the summit of the ridge is lower, but the influence of the upper sandstone is still more marked. The fields on the summit of the ridge are broad and flat and very different from those on any other crest in this field. From the standpoint of the coal content this is fortunate, as a good body of the Hance coal has been preserved notwithstanding that north of this road the coal is usually within 75 feet of the crest of the hill.

An outcrop of probably the upper coal on the W. M. Bingham farm has been described by Messrs. McCreath and d'Invilliers. It is on the Brownies Creek side of the ridge and only 30 to 40 feet below the top of the ridge. It shows a total of 3 feet 4 inches of coal with a 1-inch shale parting 15 inches from the top. The roof is shale. The coal here is described as rather sulphurous, the sulphur occurring both in this parting and in small irregular masses through the bed. Another bed of coal shows 30 or 40 feet lower down the same hollow.

The same coal is exposed at the spring below the W. O. Miracle house (563). The top of the coal was not seen, only 34 inches being exposed. The floor is a drab fire clay. The coal is about 40 feet below the top of the ridge and 12 to 15 feet below the base of the cliff-making sandstone.

The lower coal is again seen at the spring below Elijah Miracle's house. Except for a 1-inch clay parting 1 inch from the bottom it showed a solid thickness of 4 feet 6 inches. The roof is drab and pink shale 6 feet plus thick, and the floor drab clay 2 feet plus. At the surface end of the cut the dip is N. 37° W., an angle of from 5° to 10° N., but quickly disappears toward the hill. Mr. Creech reports the coal here to be 25 feet lower than at the Joseph Green opening.

Messrs. McCreath and d'Invilliers report a still better section of this coal as found on the Richard Risner place, not seen by us. It is reported as on the crest of the ridge facing the river, but nearly 2 miles to the south. The coal shows 5 feet 10 inches thick with a 1-inch shale parting 14½ inches from the top. The roof is shale.

The quality of the Hance coals is well shown by the following analyses. These, it should be remembered, are all from samples of outcrop coal. The numbers refer to the following openings, those marked (McC.) having been sampled by McCreath and d'Invilliers and reported in their report: 541, George Pursifull farm, head of Hance Creek; 559, Phelan Risner opening, head of Pitmans Creek lower coal; 560, James L. Green's upper opening, head of Long Branch of Brownies Creek; 561, same, lower coal; 562, Joseph Green coal, head of Sam Low Branch of Hance Creek; 580, Richard Risner coal, north end of Hance Ridge.

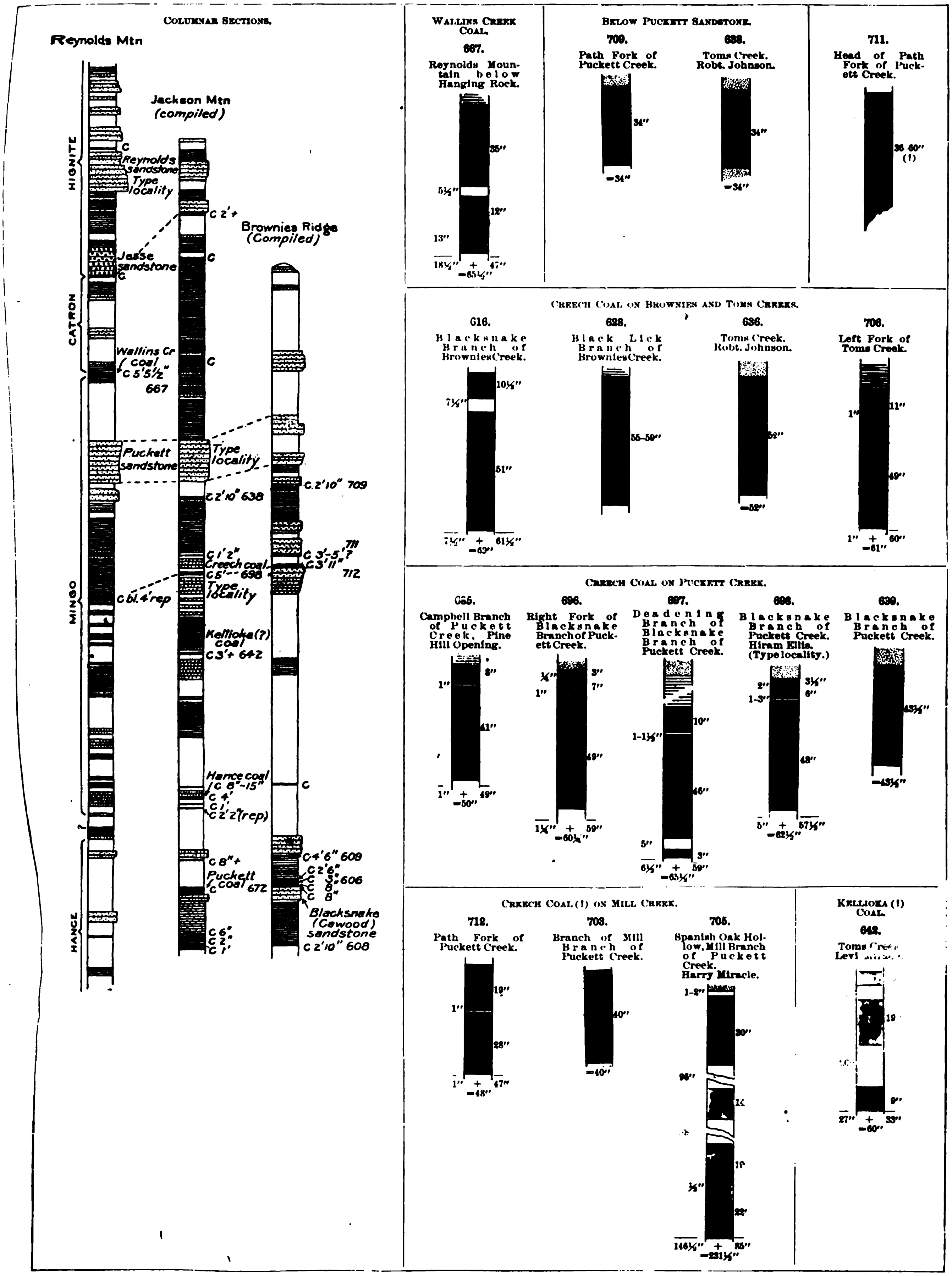
Of the above the samples obtained at 559 and 580 were of much weathered coal.

	Upper Hance.	Lower Hance.	Puckett.	Cranes Creek.
Approximate elevation, above tide ....feet..	1,700+	1,700	1,500	1,400
Thickness:				
Greatest ....do....	8	9	$4\frac{1}{2}$	$3\frac{1}{3}$
Average ....do....	$4\frac{1}{2}$	5+	$3\frac{1}{2}$	$2\frac{7}{12}$
Least ....do....	$2\frac{5}{6}$	$3\frac{1}{6}$	$1\frac{1}{2}$	$2\frac{1}{12}$
Average thickness of workable coal	$3\frac{1}{2}$	5	3+	3
Number of measurements	6	14	5	5
Area of seam..............................acres..	2,000	2,100	1,000	1,000
Total coal per acre ....tons..	5,740	8,000	5,000	5,000
Available coal per acre ....do....	4,000	6,500	4,000	4,000
Coal available in district.................do....	8,000,000	13,650,000	4,000,000	4,000,000

STRUCTURE.

This district is part of a syncline that extends entirely across the basin, the workable coal lying on the eastern and southern limb of the syncline. On Hance Creek the top of the Naese sandstone is at an elevation of about 1,120 feet at the mouth of Wolfpen Branch, of about 1,080 feet at the mouth of Pitmans Creek, of 1,070 feet at the mouth of Sam Low Branch, and of 1,000 feet, at Campbells Ford where it reaches river level. Along Hance Ridge the descent is seen by comparing the elevation of the Hance coals from south to north. Thus, starting at the south the Lower Hance coal is at an elevation of 1,820 feet on the Andy Miracle place at the head of Cubage Creek, of 1,825 and 1,810 feet at the two openings on the J. M. Miracle place. On the Julia Miracle place the elevation of the upper coal is 1,755 feet; at the head of Pitmans Creek that of the upper coal is 1,730 feet, and that of the lower coal is 1,706 feet; at the Phelan Risner place that of the lower coal is 1,669 feet. On the Jim Green farm the two coals are at elevations of 1,731 and 1,715 feet. The elevation of the coal on the W. O. Miracle place is 1,709 feet, and on the Joseph Green place 1,710. On the Elijah Miracle place the lower coal is at an altitude of 1,665 feet.

These elevations indicate that the coal dips more or less uniformly along the ridge from south to north. From the mouth of Hance Creek the rocks rise rapidly to the north; the Naese sandstone, which is at river level at Campbells Ford, is 140 feet above the river at the Seven Sisters. The axis of the major syncline crosses Hance Creek near its mouth and Brownies Creek near Oaks. In a transverse direction the dip is from Hance Creek toward Brownies Creek. Thus the Yellow Creek sandstone is below drainage along most of Brownies Creek, but it is 100 feet or more above drainage along most of Hance Creek. On Hance Ridge along the upper Sam Low road the Cawood sandstone is about 20 feet lower on the Brownies Creek side than on the opposite side, while on the same ridge along the lower Sam Low Branch road there is a difference of nearly but not quite 100 feet in the elevation of the Cawood sandstone on the two sides of the ridge, indicating torsional twisting. The coal in this ridge should therefore be mined from the north and east on the Brownies Creek side. From the Williams Spur the dip is to the west, so that the coal in that ridge would best be reached from Williams Branch or from Yellow Creek.


COLUMNAR SECTIONS.
Reynolds Mtn
HIGNITE
CATRON
MINGO
HANCE
?
C
Reynolds sandstone Type locality
Jesse sandstone
C
Wallins Cr coal C 5'5½" 667
Puckett sandstone
C bl. 4' rep
Jackson Mtn (compiled)
C 2'+
C
C
Type locality
C 2'10" 638
C 1'2"
Creech coal C 5' 698
Type locality
Kellioka (?) coal C 3'+ 642
Hance coal C 8"-15"
C 4'
C 1'
C 2'2" (rep)
C 8"+
Puckett coal C 672
C 6"
C 2"
C 1'
Brownies Ridge (Compiled)
C 2'10" 709
C 3'-5'? 711
C 3'11" 712
C
C 4'6" 609
C 2'6"
C 3" 606
C 8"
C 8"
Blacksnake (Cawood) sandstone
C 2'10" 608
WALLINS CREEK COAL.
667.
Reynolds Mountain below Hanging Rock.
35"
5½"
12"
13"
18½" + 47" =65½"
BELOW PUCKETT SANDSTONE.
709.
Path Fork of Puckett Creek.
34"
=34"
638.
Toms Creek. Robt. Johnson.
34"
=34"
711.
Head of Path Fork of Puckett Creek.
36-60" (?)
CREECH COAL ON BROWNIES AND TOMS CREEKS.
616.
Blacksnake Branch of Brownies Creek.
10½"
7¼"
51"
7½" + 61½" =63"
628.
Black Lick Branch of Brownies Creek.
55-59"
636.
Toms Creek. Robt. Johnson.
52"
=52"
706.
Left Fork of Toms Creek.
1"
11"
49"
1" + 60" =61"
CREECH COAL ON PUCKETT CREEK.
655.
Campbell Branch of Puckett Creek, Pine Hill Opening.
8"
1"
41"
1" + 49" =50"
696.
Right Fork of Blacksnake Branch of Puckett Creek.
¼"
3"
1"
7"
49"
1¼" + 59" =60¼"
697.
Deadening Branch of Blacksnake Branch of Puckett Creek.
10"
1-1½"
46"
5"
3"
6½" + 59" =65½"
698.
Blacksnake Branch of Puckett Creek. Hiram Ellis. (Type locality.)
2"
3½"
1-3"
6"
48"
5" + 57½" =62½"
699.
Blacksnake Branch of Puckett Creek.
43½"
=43½"
CREECH COAL (?) ON MILL CREEK.
712.
Path Fork of Puckett Creek.
19"
1"
28"
1" + 47" =48"
703.
Branch of Mill Branch of Puckett Creek.
40"
=40"
705.
Spanish Oak Hollow, Mill Branch of Puckett Creek. Harry Miracle.
1-2"
30"
96"
½"
22"
146½" + 85" =231½"
KELLIOKA (?) COAL.
642.
Toms Cre
Levi
19
9"
27" + 33" =60"

COLUMNAR AND COAL SECTIONS, LOWER PUCKETT DISTRICT.

Scales. Columnar sections, 1 inch=300 feet; coal sections, 1 inch=5 feet.

The best section of the coals in this region is obtained on Toms Creek.

Coals and intervals on Toms Creek.

	Ft.	in.
Interval from top of Puckett sandstone	120	0
Coal	2	10
Interval	140	0
Coal		14
Interval	40	0
Coal, Creech	5	0
Interval	180	0
Coal, Kellioka	5	0
Interval	250	0
Coal	1	3
Interval	40	0
Coal, Upper Hance	4	0
Interval	15	0
Coal	1	0
Interval	8	0
Coal, reported	2	0
Interval	120	0
Coal		8
Interval	60	0
Coal	2	6

A detailed section of the upper part of the section is as follows:

Section on Toms Creek.

	Ft.	in.
Sandstone, massive, cross-bedded	20	0
Sandstone, brown, thin bedded	50	0
Interval, hidden	8	0
Shale, drab, sandy	5	0
Interval, appears to contain a coal	8	0
Sandstone, drab, shaly	2	0
Clay shale, drab	2	0
Sandstone	2	0
Shale, sandy, blue	2	0
Sandstone, shaly, thin bedded and cross-bedded	6	0
Shale, drab	8	0
Sandstone, sandy, dark blue	2	0
Coal	2	10
Sandstone, thin and irregularly bedded	3	0
Shale, dark gray to black, very sandy, "fake"	112	0
Shale, black		6
Coal	1	2
Shale, drab, hard	9	0
Sandstone, brown, thin bedded and cross-bedded	25	0
Coal, Creech	5	0
Sandstone, massive, cross-bedded	50	0
Shale, drab, sandy	2	0
Sandstone, drab, shaly	3	0
Interval, hidden	35	0
Sandstone, brown	5	0
Shale, brown, sandy	10	0
Interval, appears to be shale	60	0
Sandstone, thin bedded	3	0
Shale, dark drab	3	0

On Puckett Creek this section occurs above Hobbs's mill:

Section above Hobbs's mill on Puckett Creek.

Number on map.	Stratum.	Thickness. Ft.	Thickness. in.
	Sandstone, coarse grained, hard, making cliff	30	0
	Interval	10	0
	Sandstone, shaly, thin bedded	10	0
	Interval, apparently all sandy shale	150	0
	Sandstone, hard, cliff making	20	0
	Interval, hidden	20	0
	Sandstone, muddy	1	6
	Shale, light drab	2	6
672	Coal, Puckett, upper bench	2	4
	Clay shale, drab	2	0
	Sandstone, shaly	10	0
	Shale, blue, with concretions	10	0
	Coal, bright, middle bench	1	6
	Fire clay		6
	Shale, drab to brown	8	0
	Coal, lower bench	1	8
	Interval, shaly sandstone ledges in part	8	0
	Shale, dark	20	0
	Sandstone, shaly, brown	1	0
	Shale, fissile, drab	65	0
	Coal		6
	Shale, drab	8	0
	Coal		2
	Shale		3
	Sandstone, shaly	1	6
	Shale, dark drab		6
	Coal	1	0
	Clay shale, drab	2	0

A number of coals have been opened on upper Path Fork which show the following thicknesses and intervals:

Coals and intervals on head of Path Fork of Puckett Creek.

	Ft.	in.
Coal, elevation 2,430	2	10
Interval	114	0
Cannel-like shale	6	6
Interval	71	0
Coal crop	[a]5	0
Interval	30	0
Coal, Creech	4	0
Interval	320	0
Coal	3+	0
Interval	115	0
Coal	2	8

[a] 3 to 5 feet.

COALS.

COAL OF LEE SANDSTONE.

Two openings have been made on a coal of workable thickness in the Lee sandstone of Pine Mountain in this district. One of these, opening on the D. H. Green place (632), shows 25 inches of solid coal. Over the coal is 12 feet of drab fissile shale, with 10 feet of shale partly hidden above. Over that is the massive sandstone of the formation. Under the coal is 5 feet of drab and yellow fire clay to sandstone. The coal dips S. 35° E. at an angle of 48°. Both the coal and shale are cross jointed by pressure. A little farther east on the I. N. Creech place (633) what was apparently the same coal has been again opened. It shows here a thickness of 5 feet at the face of an entry, which extends 100 feet or more in the hill. At the entry the coal is not so thick; the greater thickness appears to be due to the crushing and squeezing to which the coal has been subjected. The coal is very hard and has to be shot down after undercutting. The roof in the mine appears to be excellent, hard, and smooth, and not greatly affected by pressure. The roof shale is 33 feet thick beneath a massive ledge of sandstone; the dip here is S. 34° E. at an angle of 40°. This coal is thought to be equivalent to the Tunnel coal, formerly mined on the Cumberland Gap road, as it appears to occupy a similar stratigraphic position. No trace of the Cumberland Gap coal has yet been found in this district (Pl. XXI).

COALS OF HANCE FORMATION.

PUCKETT COAL.

The correlation of this coal has been much in doubt. As already stated, the Hance coal, which has a good workable thickness on Hance Creek and along Brownies Creek, is represented on Puckett Creek by a coal much divided or else has not been found or has run out. The coal found along lower Puckett Creek, about 100 feet above the creek bed but reaching creek level near the mouth of Mill Creek, was in the field thought to be the equivalent of the Hance coal on Toms Creek. Several facts, however, cast doubt on that correlation. In the first place the coal on Puckett Creek is usually split into two or three decided benches separated by an interval of varying thickness, and the benches themselves are usually thin. In the next place the distance from the Puckett sandstone to this coal on Puckett Creek is much greater than the distance from the same sandstone to the Hance coal on Toms Creek. There is, however, a strong dip to the east from the center of Jackson Mountain toward Puckett Creek, and it was thought that this dip might account for the difference in interval. On Puckett Creek, as far as Lee Branch and Bear Tree Branch, this coal appears to be equivalent to the 34-inch coal found near the mouths of those branches. About 200 feet higher occurs a 4-foot coal that is thought to be equivalent to the Harlan coal, as it has been traced up Martins Fork just over the ridge. As before stated, there is reason to think that the Hance coal occupies practically the same stratigraphic position as the Harlan coal, and this fact and other conditions mentioned have led to the assumption that the coal along lower Puckett Creek lies about 200 feet below the Hance coal, and is the representative of the Bingham coal on Toms Creek and of the coal close to the schoolhouse on Blacksnake Branch of Brownies Creek. This correlation seems to be borne out by a study of the sandstones of the region. At most points where this coal is seen on lower Puckett Creek there is below it a fairly massive sandstone, which makes cliffs in places. An attempt made with great care to trace the Cawood sandstone from the region around Harlan to Puckett Creek seemed to indicate that the sandstone immediately below the Puckett coal is the equivalent of the Cawood sandstone. Therefore in this report the Puckett coal is considered to be

distinct from the Hance coal and to occur stratigraphically just above the Cawood sandstone. A little above the Puckett coal there is another cliff-making sandstone which was at first thought to be identical with the cliff-making sandstone above the Hance coal, especially as developed on Hance Creek. On Wallins Creek, however, there is a cliff-making sandstone 40 or 50 feet above the Cawood sandstone, with a coal between, and this coal is supposed to be the equivalent of the Puckett coal on Puckett Creek. In places the Puckett coal shows three benches about equally separated; in other places, however, it appears in two quite distinct benches. This latter condition is particularly noticeable on Blacksnake Branch of Puckett and Bull Branch of Puckett. In some places, where coal outcrops are long distances apart, there has been some question as to whether the coal found belonged to the Hance coal horizon or to the Puckett coal horizon. Thus, on upper Brownies Creek (604) near the lower end of the road from Brownies to Path Fork, just above Lee & Saylor's store, an exposure of coal shows a total thickness of 70½ inches and is immediately under a massive sandstone. This coal shows an upper bench of 30 inches, including a 2-inch parting 2 inches from the roof; then below 7½ inches of parting is a 5-inch bench separated by 10 inches of clay from an 18-inch lower bench. The massive sandstone immediately over this coal can be traced some distance down Brownies Creek. Near the Eads house there is an opening on apparently the same bed showing 44 inches of solid coal (609). A short distance up the second right-hand branch of Mill Creek of Puckett is a coal in three benches. The upper bench is 19 inches thick, and is separated by 18 inches of clay from a 7-inch bench, which in turn is separated by from 3 to 6 inches of clay from a 10-inch bench. Over the coal is 7 inches of shale and 1 foot of black bituminous shale or "cannel slate," with 8+ feet of drab and brown clay shale above. The coal here (702) dips N. 10° E. at an angle of 3°. Near the mouth of Mill Creek (700) an opening shows a 5-foot coal also in three benches, though quite different from the former. The upper bench is here only 6 inches thick, and 10 inches below it is an 18-inch bench, below which are 1 inch of bone, 3 inches of coal, 5 inches of shaly coal, and another 18-inch bench of coal. At places along Mill Creek the dip appeared to be just about equal to the grade of the stream, so that there was some doubt whether these two coals were identical or whether the one at the mouth of the stream, which is believed to be the representative of the Puckett coal farther down the stream, is much below the other. If the two openings on Brownies Creek near Lee & Saylor's store and near the Eads house are on the Hance coal, then the Puckett coal on Brownies Creek is represented by a much split-up coal occurring 50 feet or more below. Thus on the Palestine Howard place on Brownies Creek this coal (610) shows an upper bench 29 inches thick separated by 19 inches of shale and 3 inches of coaly shale from 3 inches of coal, below which come 3 inches of shale, 17 inches of clay, and 6 inches of coal, with probably coal and clay below.

What is supposed to be the equivalent of the Puckett coal on Brownies Creek shows near the schoolhouse on Blacksnake Branch of Brownies Creek (614) just above the massive sandstone which causes such a waterfall in that branch. The bed here shows 25 inches of solid coal. There may be other benches not exposed. On Brownies Creek not far below the county line (606) the coal shows at the bottom of the bluff just above creek level. At this point there is 26 inches of coal just below 25 feet of black and dark-drab fissile shale. Under it there are from 2 to 7 feet of drab shale and laminated sandstone (the interval becoming smaller upstream), 3 inches of coal, 1 foot of drab shale, 8 inches of coal, 2 feet of drab shale, and 8 inches of coal, with drab shale below. On Toms Creek the Puckett coal is supposed to be represented by the coal on the Elijah Bingham place (654), a short distance up the right-hand fork. The coal here shows 31 inches of solid coal, with two 4-inch benches separated by 4 inches of clay, 12 inches below the main bench. The roof is shale and there is 12 feet of clay shale below the lower 4-inch bench. On Puckett Creek there are one or two openings on this coal on the left-hand side going up, below what is called the Uplands. One of these on the Frank Creech place (670) showed 25+ inches of solid coal. Over it there are 3 feet of blue shale and shaly sandstone above. The massive cliff-making sandstone shows about 20 feet above. A section at Hobbs's mill showing the coal in three benches (672) has already been given. Up Pounding Mill Branch of Puckett Creek (674) the lower coal shows a thickness of 2+ feet; the upper coal, which shows a short distance above, is reported to be 3 or 4 feet thick. On the Millard Creech place, between Pounding Mill Branch and Bull Branch of Puckett, this coal (675) shows three benches 16 inches, 26 inches, and 8½ inches, respectively, separated by 19 inches of dark clay above and 9 inches of dark clay as a lower parting. The roof is of dark-clay shale. At the mouth of Bull Branch on the east side the following section appears:

Section of Puckett coals and accompanying strata at mouth of Bull Branch.

No. on map.	Stratum.	Thickness.		No. on map.	Stratum.	Thickness.	
		Ft.	*in.*			*Ft.*	*in.*
676	Coal, exposed	1	6+		Shale, brown	2	6
	Fire clay, brownish drab	1	6		Sandstone, brown to gray	3	0
	Shale, brown and drab	4	0		Shale, brown	3	0
	Sandstone, shaly	4	0		Sandstone, shaly, brown to gray	3	0
	Slope, hidden	5	0		Shale, brown and light drab	3	0
	Shale, drab, disturbed	1	6		Shale, harder	1	0
	Coal and dark-drab clay, mixed		[a]6		Shale, light drab and brown	5	0
	Clay, light drab, soft		3		Hidden by talus	60	0
	Coal and light-drab shale		3		Shale, drab, poorly exposed	20	0
	Clay, drab		2		Flagstone, shaly, light drab, breaking into thin slabs	6	0
677	Coal	1	1		Shale, drab, fissile, to creek level	12	0
	Clay, brown		1½				
	Coal	1	9				
	Fire clay, brownish drab	1	6				

[a] 4 to 6 inches.

Up Bull Branch on the Abraham Slusher place both coals can be seen (679, 680); the lower coal is just at creek level, the upper coal about 20 feet above. The upper

Taken as a whole, the Puckett seam is seen to contain from 3 to 6 feet of coal, but only in places is enough of this in a single bench to make it minable. Up Blacksnake Branch of Puckett Creek the lower bench appears to have a workable thickness. The upper bench, though a little thicker in the same area, is too much cut by partings to be of value. On the whole, it may be doubted if this coal should be classed as a workable coal, though it may prove to be so toward the west; particularly if we have been mistaken in our correlations, and exploitation should show that this is the same as the Hance coal on Toms Creek.

No coals of good workable thickness were found below this level stratigraphically in this area. Near Lee & Saylor's store a lower coal is seen in the creek bed, upturned by the Brush Mountain fold, so that it dips N. 10° W. at an angle of 70° to 80°. Near the schoolhouse on Brownies Creek (608) a coal of unknown but probably of not workable thickness is exposed in the side of the creek bank and is much broken up by faulting (608). On the Wilson place a short distance farther down Brownies Creek what is probably the same coal (611) is faced up, showing two benches of 17 inches each separated by 7 inches of drab shale. On lower Brownies Creek near Oaks what is probably the same coal has been dug into at several points close beside the road; as nearly as could be measured it showed two benches of which the upper was 16 inches, the lower 21 inches, with 10 inches of clay between. Eight feet of massive shaly sandstone outcrops immediately above. On the Cumberland River just below the mouth of Puckett Creek on the Hoskins place some coal has been dug from two beds about 60 feet apart (668 and 669). A section at this place shows as follows:

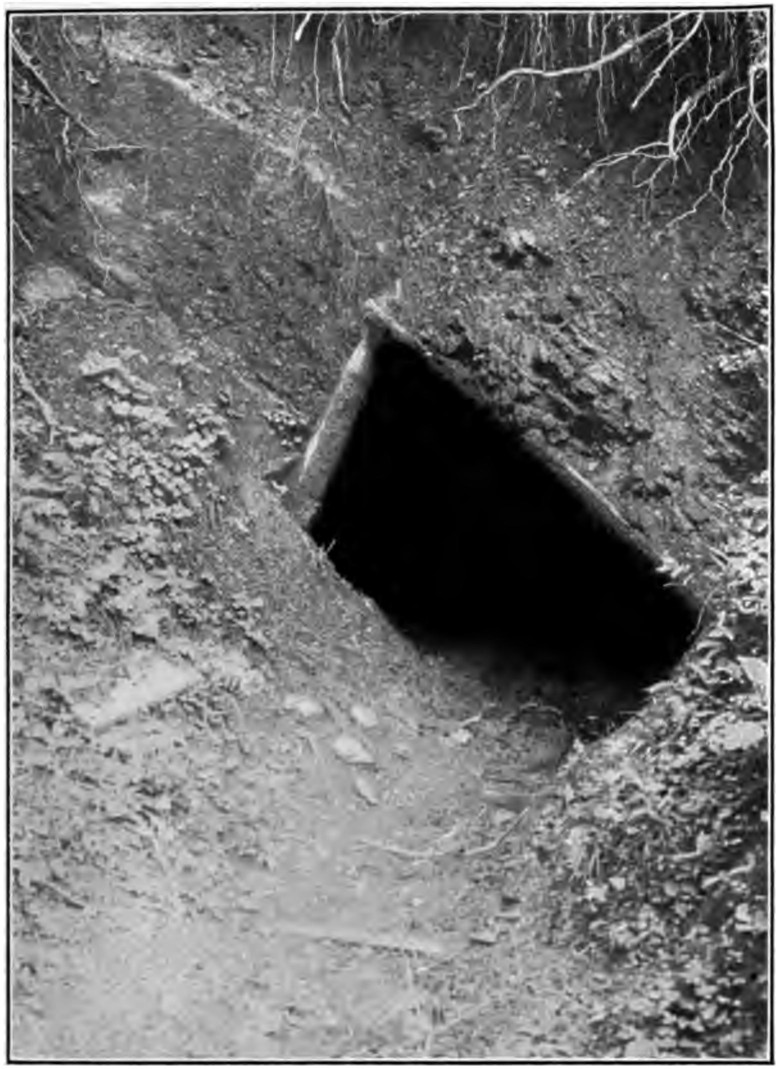
Section on Cumberland River near Callaway post-office.

No. on map.	Stratum.	Thickness.	No. on map.	Stratum.	Thickness.
		Feet.			*Feet.*
	Sandstone	10	669	Coal has been mined, not exposed	....
	Shale, drab, fissile	30		Shale, sandy	15
	Sandstone, shaly	10		Sandstone, crinkly bedded	12
	Coal, not exposed	....		Sandstone, more massive	6
	Interval	15		Sandstone, thin and crinkly bedded, to the river level	40
	Sandstone	5			
	Shale, sandy	20			
	Shale	20			

This is north of the synclinal axis and the rocks dip to the southeast at an angle of 10°. At Hobbs's mill 1 foot of coal at creek level (678) has already been mentioned.

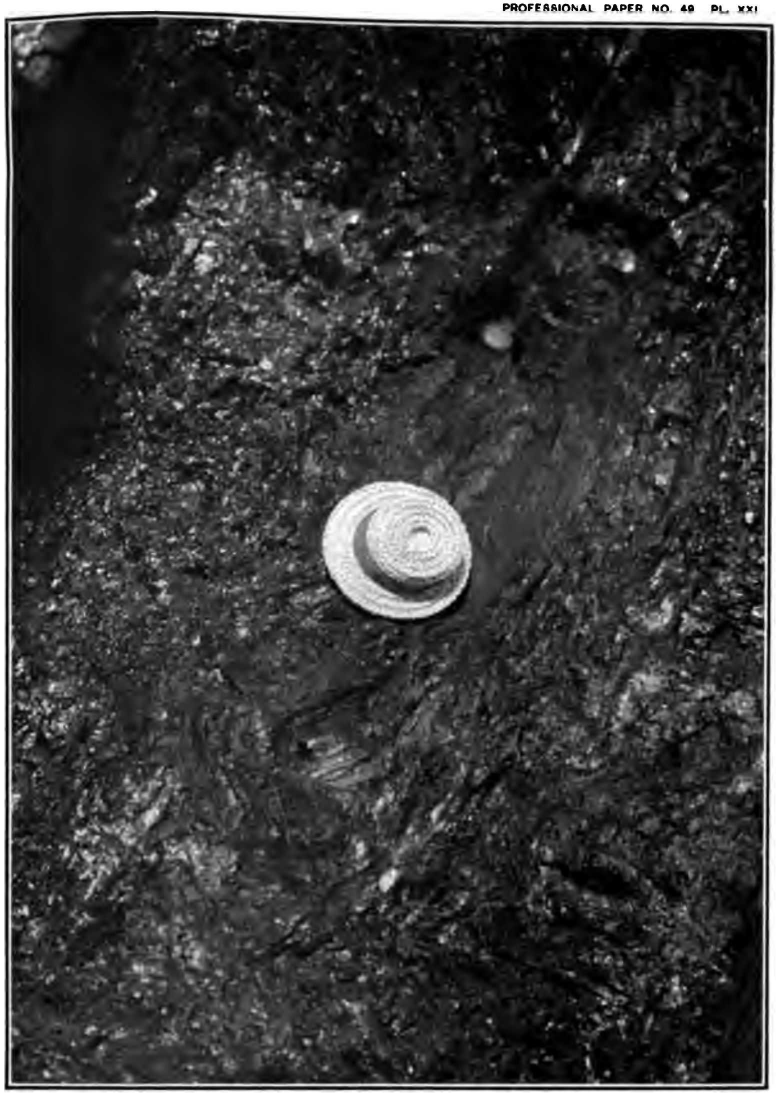
COALS OF MINGO FORMATION.

A 34-inch coal is noted in this formation about 120 feet below the top of the Big Cliff sandstone in the section on Toms Creek. The section at the head of Path Fork showed a coal of similar thickness at apparently the same horizon.



A. PINE MOUNTAIN COAL ON I. N. CREECH PLACE.

Exterior view, showing dip of coal and shale roof.



B. COAL AT FACE OF I. N. CREECH MINE.

View showing seam more or less distorted.

There is thus suggested a coal of barely workable thickness near the top of this formation. Its roof in both cases is sandstone. On the Toms Creek section it has also a sandstone floor, which would seriously affect its workability.

HANCE COAL.

On the Brownies Creek side of Jackson Mountain, and through Toms Creek, what appears to be certainly one of the Hance coals presents a good workable thickness. From the fact that at several openings a small coal has been found a few feet lower it has been assumed that the main coal in this area is the equivalent of the Upper Hance coal. On Blacksnake Branch of Brownies Creek, where this coal is certainly recognized, it shows a thickness of a little over 3 feet, with a 1½-inch parting 12 inches from the bottom. This is on the A. Slusher place (691). On the main fork of Stone Coal Branch of Brownies Creek the lower coal (618) shows a thickness of 2 feet 9 inches. A short distance up the middle fork of Stone Coal Branch on the Judge Morse place the upper coal shows a thickness of 6 feet 3 inches, including 7 inches of shale 2 feet 3 inches from the bottom. The roof is of light-drab and brown shale. Nine feet below, with sandy shale between, is the lower coal 2 feet 10 inches thick. On the left-hand fork of Stone Coal Branch an even better showing is made. Here the seam has a total thickness of 73½ inches, of which 71 inches are coal; there is a half-inch parting 25 inches from the top and a 2-inch parting 28 inches from the bottom. The roof is a light-brown clay shale. On Hoskins Branch of Brownies Creek, on the Thompson place (602), this coal is reported to be 4 feet thick without partings. On the right-hand fork of Toms Creek, at the Elias Hoskins place (651), the coal has been faced up at the spring, and shows 48 inches of coal. The roof is of drab clay shale; the floor is a light-drab fire clay. On Long Branch of Toms Creek, on the Robert Johnson place (645), the coal shows 3 feet 10 inches of solid coal. Eight feet above are 8 inches of coal with a 1-inch clay band in the middle, and 15 feet below are about 1 foot of coal and 5 to 6 feet of sandstone. Eight feet lower is reported 2 feet of coal under a light-drab sandy shale. Where this horizon crosses Long Branch 32+ inches of coal are exposed. On the Slusher heirs place on Toms Creek (635) the coal is over 4 feet thick with a 3-inch parting from 5 to 6 inches from the top. This parting consists of 1 inch to 1½ inches of light-brown or gray clay, 1 inch to 0 of coal, and 1 inch to 1½ inches of drab clay at the bottom. The roof is dark clay shale. Eighteen feet below an 18-inch coal has been faced up. Directly across Toms Creek, at the Carlo Arnett opening (634) the coal is 54½ inches thick. It shows the same triple parting 6 inches from the top, which here runs from 2½ to 3 inches thick. It is made up of from 1 to 4 inches of clay averaging 1½ inches, one-half to 4 inches of coal averaging 2 inches, and from 1 to 2 inches of clay averaging 1½ inches. There is a half-inch streak of soft coal 22 inches from the bottom. Over the coal there are 7 feet of brown to drab shale, overlain by 6+ feet of brown sandstone; there appears to be about 1 foot of drab slate. The coal is here 1,476 feet above tide, or 110 feet above the creek. This coal is again seen near the mouth of Toms Creek and 300 feet above the creek (658). Here it shows 3 feet 9 inches of coal, with from one-half to 2 inches of soft coal 3½ inches from the top. On the north side of Cumberland River, in Tanyard Hill (663), is an old facing on this coal, reported to show 4 feet 4 inches. As given in these sections, this upper Hance coal shows an average thickness of about 4 feet, practically all of which is workable. Its greatest thickness shows 71 inches of coal. In determining the area underlain by it the difficulty is at once noticed that on the Puckett Creek side of Jackson Mountain either this coal has not been recognized or it has thinned out, or it has become unworkable, so that we are not able to say how far through the mountain it maintains the workable features shown on the west side. As in the preceding district this coal is correlated with the Bennett Fork coals of the Bennett Fork district. Of still more interest, it is supposed to be equivalent to the Harlan coal, which makes such a fine showing all through the eastern part of the field and which is believed to show at the head of Puckett Creek. There therefore seems to be some warrant in believing that this coal, like the Creech coal above, has escaped observation on the Puckett Creek side and that, therefore, it may prove workable entirely through the mountain. With our present information we will assume it to be workable only halfway through the mountain.

The following analyses will indicate somewhat the character of this coal:

Analyses of the Hance coal in Jackson Mountain.

Constituent.	A.	B.	C.	D.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	1.608	6.636	2.60	1.162
Volatile hydrocarbons	34.812	35.264	33.20	36.428
Fixed carbon	51.623	51.758	59.60	54.436
Ash	10.680	5.650	4.60	6.605
Sulphur	1.277	.692	.931	1.369

A. Judge Morse place on middle fork of Stone Coal Branch.
B. Slusher heirs, Toms Creek.
C. Stone Coal Branch of Brownies Creek; analyzed by Robert Peter.
D. Elias Green place, Toms Creek; analyzed by A. S. McCreath; sample gathered by McCreath and d'Invilliers.

KELLIOKA COAL.

This coal, which gives some promise of yielding workable coal to the east of this region, was not certainly recognized in this area; at least no coal was found showing anything like the thickness found in the eastern district. The only point at which coal at about this horizon could be measured was on the Levi Miracle place on Toms Creek (642); here the seam shows 60 inches, all told, of which but little more than one-half is coal. It occurs in three benches. The upper bench is 5 inches thick and is separated by 7 inches of dark-drab clay from a 19-inch bench, below which is 20 inches of light-drab clay and then 9 inches of coal. The roof is a gray clay shale. It resembles the Kellioka coal in its split-up condition, but hardly shows as much actual coal as is usually found in that seam to the east. As other data are lacking it may be assumed that this is the same coal, and if this section is representative of that coal in this district it may be dismissed as not workable.

CREECH COAL.

Probably the best coal in this district, as far as known, is the 5-foot coal made known by a large number of facings which were made in 1902 under the direction of Mr. Robert Creech around Jackson Mountain. This coal offers an interesting illustration of the fact that a coal of good workable thickness may exist in these mountains and be entirely unknown because conditions do not favor its being exposed in natural outcrop or its producing coal blooms that attract attention and exploitation. Practically all of our data on this coal were obtained from the facing mentioned. On Blacksnake Branch of Brownies Creek this coal shows a thickness of 5 feet 9 inches, with a 7½-inch clay band 10½ inches from the top. On Black Lick Branch of Brownies Creek it is from 55 to 59 inches thick without partings. The roof there is shale. On Toms Creek on the Robert Johnson place (636) it is 52 inches thick without partings and has a sandstone roof. On the left-hand fork of Toms Creek on the Slusher heirs place it is 5 feet 1 inch thick, the 1-inch parting being 11 inches from the top. Between it and the sandstone roof there is 10 inches of shale and coal. The floor shows a slight dip to the southeast. Its elevation here is 1,960 feet. Passing around the end of Jackson Mountain this coal has first been faced on Campbell Branch of Puckett Creek at the Pine Hill opening (685). Here it is 4 feet 2 inches thick with a 1-inch parting 8 inches from the top. The roof is of shaly sandstone. On the right fork of Blacksnake Branch of Puckett Creek (698) it is practically 5 feet thick, with a parting one-fourth inch thick 3 inches from the top and a 1-inch parting 7 inches lower down. The roof is of gray sandstone. On the Deadening Branch of Blacksnake Branch of Puckett Creek on the Mack Johnson place (697) it shows a thickness of 5 feet 5 inches, including a 5-inch parting 3 inches from the bottom and a 1- to 1½-inch parting 10 inches from the top. Above the coal are 2½ feet of drab shale with 12+ feet of dark-gray sandstone. The coal here, as at the next place, is unusually bright. The main mud slips run S. 40° W. On the Ellis Branch of Blacksnake Branch on the Hiram Ellis place the coal is 62½ inches thick, with a ⅛-inch parting 3½ inches from the top and a 1- to 3-inch parting 6 inches lower. The roof is of laminated sandstone. At the head of Blacksnake Branch the coal is somewhat thinner, showing only 43½ inches under a gray micaceous sandstone (699). The openings so far mentioned are so close together and their relation to the Puckett sandstone is so constant that there can be little doubt of their all being on the same bed. Southward on Jackson Mountain, where the Puckett sandstone is not as distinct and where there are only a few old facings on what appears to be this coal, the correlation is less certain. On Jackson Mill Branch of Puckett Creek (703) a 40-inch solid coal was found at about the same horizon and is supposed to represent the Creech coal. On Spanish Oak Hollow of the same branch (705) this coal shows 41 inches thick, with a ½-inch parting 19 inches from the top. At this point, however, two other coals show a short distance above, the first a 14-inch bench 4 feet above, the second a 30-inch bench 8 feet above that. The roof over the upper bench is sandstone. On Path Fork of Puckett Creek (712) occurs a 4-foot coal with a parting 19 inches from the top, which is supposed to be the Creech coal. Thirty feet above it a coal is partially exposed which seems to have a thickness of from 3 to 6 feet. This may be the representative of the 30-inch bench of coal in the Spanish Oak Hollow and may be the equivalent of the 1 foot 2 inches of coal a similar distance above the Creech coal on Toms Creek. Until further exploration has been made on this upper coal we are not prepared to discuss its workability or persistence. In Reynolds Mountain the only trace found of the Creech coal was a bloom where the coal is reported to be 4 feet thick. Its presence, persistence, and workability on that mountain are, therefore, problematical. In the northern end of Jackson Mountain, however, and possibly all through Jackson Mountain it presents a good thickness. The following analyses indicate a good quality. It is fairly high in the hill, so that its area is limited. But as it is below the massive Puckett sandstone, its area is much greater than if it were above that sandstone.

Analyses of the Creech coal in Jackson Mountain.

Constituent.	A.	B.	C.	D.	E.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Water as received	8.776	6.382	....	....	....
Water (powdered coal)	5.100	3.020	1.350	2.232	3.492
Volatile combustible matter	35.270	38.040	38.760	36.518	35.308
Fixed carbon	53.101	55.468	55.847	56.257	57.392
Ash	5.840	2.800	3.330	4.080	3.200
Sulphur	.689	.762	.713	.913	.609
Phosphorus	.003	....	....	....	....

All analyses by A. S. McCreath, from samples obtained in 1902 and 1903.
A. Mack Johnson place, Deadening Branch of Blacksnake Branch of Puckett Creek.
B. Slusher heirs opening, Toms Creek.
C. Hiram Ellis, Ellis Branch of Blacksnake Branch of Puckett Creek.
D. Harvey Miracle place, Spanish Oak Hollow, near head of Jackson Mill Branch of Puckett Creek.
E. Path Fork of Puckett Creek.

The first of these analyses is of badly weathered coal, as shown in the amount of water contained, and, as might be expected, the coke was barely coherent, but what this coal would do under better circumstances is probably indicated by the other analyses on the same bed, taken but a short distance away. This shows the coal to be fairly low in ash and in sulphur, and to have about the average amount of fixed carbon that occurs in the coals of this region. The crucible test showed the coke to be of fair quality, but with a tendency toward a granular and therefore rather weak structure, and in this case, as in most other cases in this field, the coal was obtained from a facing but a few feet deep, and, therefore, probably slightly weathered, a fact which may have affected the character of the coke.

COAL OF CATRON FORMATION.

One or two coal blooms in the upper part of this formation close below the Jesse sandstone suggest the presence of coal of some thickness that is possibly workable. Near the top of Jackson Mountain a little back from Walnut Cove, near the northern end, 20 inches of coal were seen immediately below the massive sandstone cliff. The coal at this point or near here was reported to be 7 feet thick. The sandstone roof of the coal here is very irregular. One or two other blooms were seen below this, but of the coal at these points nothing is known. At the bottom of the formation is the Wallins Creek coal, of which only one measurable section was seen, on the west side of Reynolds Mountain below Hanging Rock. It had a total thickness of 5 feet 5½ inches; the lower 13 inches were bony, and there was a 5½-inch parting 35 inches from the top; the roof is shale. No analyses of this coal collected in this area have been made, so that its character and thickness must be judged from the more eastern districts, where it is better known.

COAL OF HIGNITE FORMATION.

One or two coal blooms were seen in the rocks along the crests of Reynolds Mountain, but at no place were they exposed so as to show the character and thickness of the coal. Considering the small area covered by this formation it may be considered to carry no workable coals.

SUMMARY.

Summary of coals of the Lower Puckett district.

Number of coal beds found		25
Total thickness of coals	feet..	30–40
Number of coal beds of workable thickness (locally)		9
Average thickness of principal workable coals	feet..	4½
Total thickness of workable coal beds	do....	20
Greatest thickness of single coal bed measured	do....	10¾
Greatest thickness of coal in single bed measured	do....	$7\frac{1}{12}$
Approximate area underlain by workable coal	square miles..	10–20
Estimated available tonnage of district	tons..	40, 000, 000

		Creech.	Hance.
Approximate elevation above tide	feet..	2, 000	1, 400
Thickness:			
Greatest	do....	5¾	6¼
Average	do....	4½	4⅛
Least	do....	3⅓	$3\frac{1}{12}$
Average thickness of workable coal	do....	4½	4
Number of measurements		12	9
Area of seam	acres..	3, 000	6, 000
Total coal per acre	tons..	7, 380	6, 560
Available coal per acre	do....	6, 000	6, 000
Coal available in district	do....	12, 000, 000	30, 000, 000

STRUCTURE.

As in the preceding districts, the general structure here is synclinal, the main axis crossing Brownies Creek near Oaks and Puckett Creek near the mouth of Bull Branch. The workable coals are almost entirely confined to the southern limb. On Puckett Creek, within this district, the dip almost exactly corresponds with the gradient of the stream. What is supposed to be the Puckett coal is at stream level near the junction of Lee Branch, Bear Tree Branch, and Rockhouse Branch. It is again just above creek level on Mill Creek, just above the mouth of that creek where Puckett Creek enters this district. From there downstream the coal gradually rises above the creek level until at the mouth of Campbell Branch it is about 120 feet above the creek. A somewhat similar dip is seen following the crest of Jackson Mountain and Brownies Ridge. In a transverse direction the dip which was found to extend from Hance Creek to Brownies Creek is continued, so that the formations that were exposed along that creek and were just below creek level on Brownies are deeply buried along Puckett Creek. The 1-foot coal at Hobbs's mill on Puckett Creek just at creek level is stratigraphically about in the position of the coal at the Lum Green opening on Hance Creek, which is 220 feet above creek level. This northeastward dip is very well seen on Blacksnake Branch of Puckett Creek, either by tracing the sandstone, which makes fairly prominent outcrops, or by the levels on the coal lying just above. Thus the Puckett coal near the mouth is estimated to have an elevation of 1,245 feet, while the same coal at the Anthony Ely opening, near the mouth of Deadening Branch, has an elevation of about 1,425 feet. From Puckett Creek northeastward the strata rise again, suggesting that the lower course of Puckett Creek follows the axis of a transverse syncline. On the road from Puckett Creek to Cumberland across the Uplands this rise is very marked, though in this case part of the rise may be ascribed to the fact that we are north of the main synclinal axis.

WALLINS CREEK DISTRICT.

GEOGRAPHY.

This district includes the mountains on the south side of Cumberland River from the eastern side of Lower Puckett district along Puckett Creek to Jackson Mill Branch; its boundary extends thence down Sang Branch of Wallins and up Wallins to Banners Fork, up the branch of Banners Fork across Potato Hill Ridge, down Little Creek to Catron, and north of west on a straight line to Pine Mountain. The limits have been governed partly by the size of the page[a] and partly by the fact that within this district our knowledge of the Harlan coal is very uncertain. The Harlan coal has been traced in all the area immediately east and south of this district. Aside from Cumberland River the three principal valleys are Wallins in the center, and Forrester and Ewing on either side, with Jesse Creek between Forrester and Wallins. Wallins Creek has a larger amount of bottom land than most of the streams of this region, probably due to the fact that it is a little longer. The ridges have the same general character as in the last district, but are slightly higher. Fox Knob, at the head of Ewing Creek, with an elevation of 3,416 feet, is the highest point within this field, being exceeded on the map only by the highest point at the Butts of the White Rocks on Cumberland Mountain. The coals of this district lie in a good position for mining, as they dip toward the main drainage lines, so that they can be worked from Forrester, Wallins, and Ewing creeks. The Southern Railway has surveyed a line up Cumberland River through this district, which, if it is built, will form an outlet for the coal of this region.

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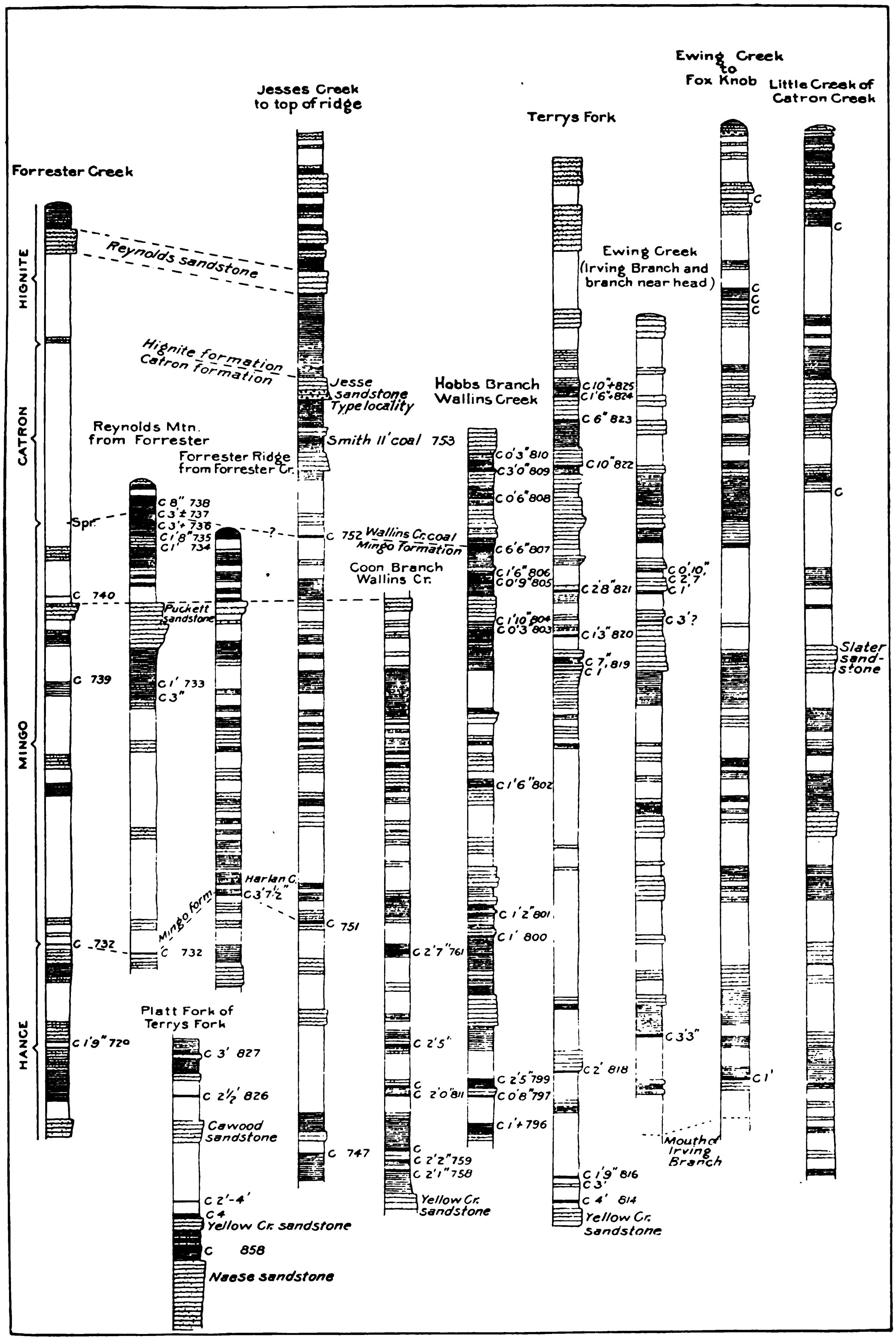
[a] The page maps have been combined into Pl. XL, in pocket.

the true representative of the Cawood sandstone and that a coal which came between the two sandstones probably occurred at the horizon of the Puckett coal, as typically exposed immediately above Hobbs's mill on Puckett Creek. A little farther up Wallins on the west side and about opposite Meadow Branch this lower sandstone makes a local cliff and shows a thickness of about 10 or 15 feet, and is overlain by a thin layer of concretionary limestone. This limestone was again recognized overlying about 15 feet of sandstone immediately opposite the mouth of Hobbs Branch and 40 feet above Wallins Creek. Near the highest point of the trail from Wallins Creek to Jesse Creek the sandstone, making a rather prominent outcrop and showing a decided rise to the west, was thought to be the Cawood sandstone. This sandstone occurs again on the west side of Jesse Creek at approximately the same level and makes several prominent cliffs on the trail from Jesse Creek to Forrester Creek. On this trail it was thought to be the sandstone outcropping on the trail 140 feet above Forrester Creek. From there it was traced with less certainty, because more poorly exposed, to Saylor Creek, where it appeared to be the sandstone making slight cliffs about 140 feet above the mouth of the left-hand fork of the creek.

This tracing of the Cawood sandstone has been mainly relied upon in the determination of the stratigraphic position of the coals of the lower part of the section. A group of sections in this district is presented on Pl. XXII.

The stratigraphy of the lower part of the section is best seen, perhaps, between the mouth of Wallins Creek and Ewing Creek, especially on the trail passing up Terrys Fork and Platt Fork of Terrys, and over to Cumberland. The Naese sandstone outcrops at river level just below the mouth of Wallins Creek. On the north side of the river farther up, from 125 to 150 feet of it is exposed. Above the mouth along Wallins Creek opposite the mouth of Terrys Fork is a massive sandstone making a small cliff, which was taken to be the Yellow Creek sandstone. Just below the mouth of Platt Fork of Terrys is the Terrys Fork coal, one-half cannel and one-half bituminous, 4 feet thick. From 5 to 30 feet above is another coal that is a foot or two in thickness and possibly is equivalent to the 4-foot coal (756). Higher on the trail a ledge of massive sandstone was crossed at an elevation of 200 feet above the Terrys Fork coal. This ledge is taken to be the Cawood sandstone. About 40 feet above it on the Jesse Howard place a 28-inch coal has been opened. Eighty feet above that and immediately over a thin layer of massive sandstone is a coal measuring 3 feet or a trifle over. The last-mentioned coal is believed to be equivalent to the thickest coals found in the lower part of the section on Ewing Creek and Wallins Creek. Some question was raised as to whether this was not the Harlan coal, which attains such importance in the succeeding districts. A careful study of the stratigraphy, however, led us to place the position of the Harlan coal in this district just above a massive cliff-making sandstone that occurs 80 to 100 feet higher. No coal was found at this horizon, unless it be the coal on the Sarah Blanton place on Forrester Creek (744). Possibly the principal objection to the 3-foot coal just described being the equivalent of the Harlan coal is the fact that it is about 100 feet nearer what was taken to be the Cawood sandstone than the Harlan coal is in the Harlan district and a corresponding amount farther below the Wallins Creek coal than the Harlan coal should lie. The sections given on Pl. XXII, opposite, may be briefly summarized as follows:



COLUMNAR SECTIONS, WALLINS CREEK DISTRICT.

Scale: 1 inch=300 feet.

Sections in Wallins Creek district.

FORRESTER CREEK FROM THE MOUNTAIN SUMMITS AT THE HEAD TO THE MOUTH.

No. on map.	Stratum.	Thickness.	
		Ft.	*in.*
	Interval	50	0
	Sandstone, Reynolds	50	0
	Interval, to where surface is covered with gritty fragments characteristic of Jesse sandstone	340	0
	Interval, to spring, probable position of Wallins Creek coal	230	0
	Interval	160	0
740	Coal, bloom	....	
	Interval	20	0
	Sandstone, Puckett	30-60	0
	Interval	90	0
739	Coal, bloom	....	
	Interval	540	0
732	Coal, bloom, Harlan (?)	....	
	Interval	200	0
729	Coal	1	9

BRANCH OF FORRESTER CREEK, ENTERING FROM THE WEST BETWEEN WOLF AND LAUREL BRANCHES.

No. on map.	Stratum.	Thickness.	
		Ft.	*in.*
	Interval	50	0
738	Coal		8
	Shale	20	0
737	Coal, Wallins Creek (?)	±3	0
	Interval, thin-bedded, shaly sandstone and shale	20	0
736	Coal with two partings	3	0
	Shale	30	0
735	Coal	1	8
	Sandstone	30	0
734	Coal	1	0
	Interval, mostly shale	100	0
	Sandstone, Puckett	80	0
	Interval, nearly all shale	70	0
733	Coal	1	0
	Interval	20	0
733*a*	Coal		3
	Interval	530	0
732	Coal, Harlan (?)	....	

DIVIDE BETWEEN FORRESTER CREEK AND JESSE CREEK OPPOSITE THE MOUTH OF LAUREL BRANCH.

No. on map.	Stratum.	Thickness.	
		Ft.	*in.*
	Interval	160	0
	Sandstone, Puckett	20	0
	Interval	570	0
744	Coal, Harlan (?)	3	7
	Interval	190	0
729	Coal	2	0
	Interval	30	0
	Sandstone, Cawood	40	0

FROM TOP OF MOUNTAIN AT HEAD OF JESSE CREEK DOWN JESSE CREEK TO MOUTH.

No. on map.	Stratum.	Thickness.	
		Ft.	*in.*
	Interval	280	0
	Sandstone, Reynolds	40	0
	Interval	170	0
	Sandstone, finely conglomeratic, Jesse, type locality	50	0
	Interval	80	0
753	Coal bloom, thick (?)	....	
	Interval	200	0
752	Coal, Wallins Creek (?)	....	
	Interval	130	0
	Sandstone, hard coarse, Puckett	20-60	0
751	Interval	600	0
	Coal bloom, Harlan (?)	....	
	Interval	190	0
	Sandstone, Cawood (?)	30	0
	Interval	220	0
747	Sandstone, Yellow Creek (?)	....	
	Coal bloom	....	

Sections in Wallins Creek district—Continued.

ON CAMP BRANCH OF WALLINS CREEK.

No. on map.	Stratum.	Thickness.		No. on map.	Stratum.	Thickness.	
		Ft.	*in.*			*Ft.*	*in.*
	Sandstone, Puckett	20+	0		Interval	40	0
	Interval	710	0		Sandstone, Cawood (?)	10	0
762	Coal	2	5		Shale	80	0
	Interval, possible position of Harlan coal	60	0	760	Coal		
	Interval	130	0		Interval	20	0
761	Coal, Ewing Creek	2	5	759	Coal, cannel	2	2
	Interval	90	0		Interval	20	0
811*a*	Coal			758	Coal, cannel	25	0
	Shale	20	0		Interval	30	0
					Sandstone, Yellow Creek	20	0
811	Coal	2	0				

ON HOBBS BRANCH OF WALLINS CREEK.

No. on map.	Stratum.	Thickness.		No. on map.	Stratum.	Thickness.	
		Ft.	*in.*			*Ft.*	*in.*
	Sandstone	50	0		Shale	1	0
810	Coal		3	803	Coal		3
	Sandstone	10	0		Sandstone, shaly, laminated	10	0
	Shale	15	0		Shale, sandy	20	0
809	Coal, Smith 11-foot (?)	3	0		Sandstone, shaly, thinly laminated	30	0
	Sandstone, massive, cross-bedded	35	0		Shale	40	0
	Interval, hidden	5	0		Interval	70	0
	Shale	10	0		Shale	10	0
808	Coal		6		Sandstone, cross-bedded and laminated	15	0
	Sandstone, shaly	6	0		Interval	25	0
	Shale	10	0		Sandstone, massive	20	0
	Sandstone, massive	55	0		Sandstone, thinly laminated	30	0
	Shale	8	0		Sandstone, massive	10	0
	Sandstone, massive	12	0		Sandstone, shaly, laminated	15	0
	Shale	15	0		Interval, hidden	15	0
807	Coal, Wallins Creek	6	6		Shale	15	0
	Shale	50	0	802	Coal	1	6
	Sandstone, shaly, laminated	15	0		Sandstone, massive	40	0
806	Coal	1	6		Interval, hidden	60	0
	Shale	15	0		Sandstone, massive	20	0
805	Coal		9		Interval, hidden	25	0
	Clay shale	30	0		Sandstone, massive	40	0
	Sandstone, massive, Puckett (?)	50	0		Shale	20	0
804	Coal	1	7		Sandstone, thinly laminated, shaly	20	0
	Clay	3	0		Shale	10	0
	Sandstone	1	0				

Sections in Wallins Creek district—Continued.

ON HOBBS BRANCH OF WALLINS CREEK—Continued.

No. on map.	Stratum.	Thickness.	
		Ft.	*in.*
	Interval, hidden	15	0
	Sandstone, cross-bedded, massive	15	0
801	Coal		2
	Sandstone	20	0
	Shale, sandy	20	0
	Shale	10	0
	Sandstone, thinly laminated	10	0
800	Coal	1	0
	Sandstone, thinly laminated	20	0
	Shale	30	0
	Sandstone, massive to laminated, partly hidden	40	0
	Shale, light drab, position of Harlan coal (?)	20	0
	Sandstone, massive, cross-bedded	40	0
	Shale	5	0
	Interval, hidden	10	0
	Sandstone	30	0
	Shale, with lenses of limestone	20	0
	Interval	60	0
799	Coal, Ewing Creek	2	5
	Interval, sandstone mostly	25	0
797	Coal		8+
	Interval, some sandstone	60	0
796	Coal	1	0
	Sandstone	8	0
	Shale	12	0
	Sandstone, Cawood	10	0
	Shale, sandy	30	0
	Interval to mouth of branch	65	0

ON TERRYS FORK OF WALLINS CREEK.

No. on map.	Stratum.	Thickness.	
		Ft.	*in.*
	Interval, mostly sandstone	70	0
	Interval, hidden	40	0
	Sandstone	40	0
	Interval, mainly sandstone	50	0
	Interval, containing some soft brown sandstone	120	0
	Sandstone, massive	40	0
	Interval	10	0
	Sandstone, shaly, thinly laminated	80	0
	Interval, hidden	10	0
	Shale, sandy	15	0
825	Coal		10+
	Sandstone, shaly, irregularly bedded	20	0
824	Coal	1	6+
	Sandstone, massive	50	0
823	Coal		6
	Shale, black		6
	Clay shale	50	0
	Sandstone, cross-bedded	40	0
	Shale, bituminous, black		8
822	Coal		2
	Sandstone, thinly laminated	35	0
	Interval, some thinly laminated sandstone	25	0
	Sandstone, massive	60	0
	Sandstone, shaly	40	0
	Interval, position of Wallins Creek coal (?)	10	0
	Sandstone, hard, making a rockhouse	5	0
	Clay shale	15	0
	Interval, hidden	40	0
	Sandstone	10	0
821	Coal	2	8
	Sandstone, thinly laminated	20	0
	Interval, hidden	30	0
	Sandstone, massive	10	0
	Interval	10	0
	Sandstone	5	0
	Shale	5	0
	Interval	10	0
820	Coal	2	0
	Interval	25	0

than at the position of the Puckett sandstone, the latter having run out or become inconspicuous. The approximate position of the Harlan coal in the lower part of the section is suggested by known elevations of the Harlan coal a mile or two either side of this section.

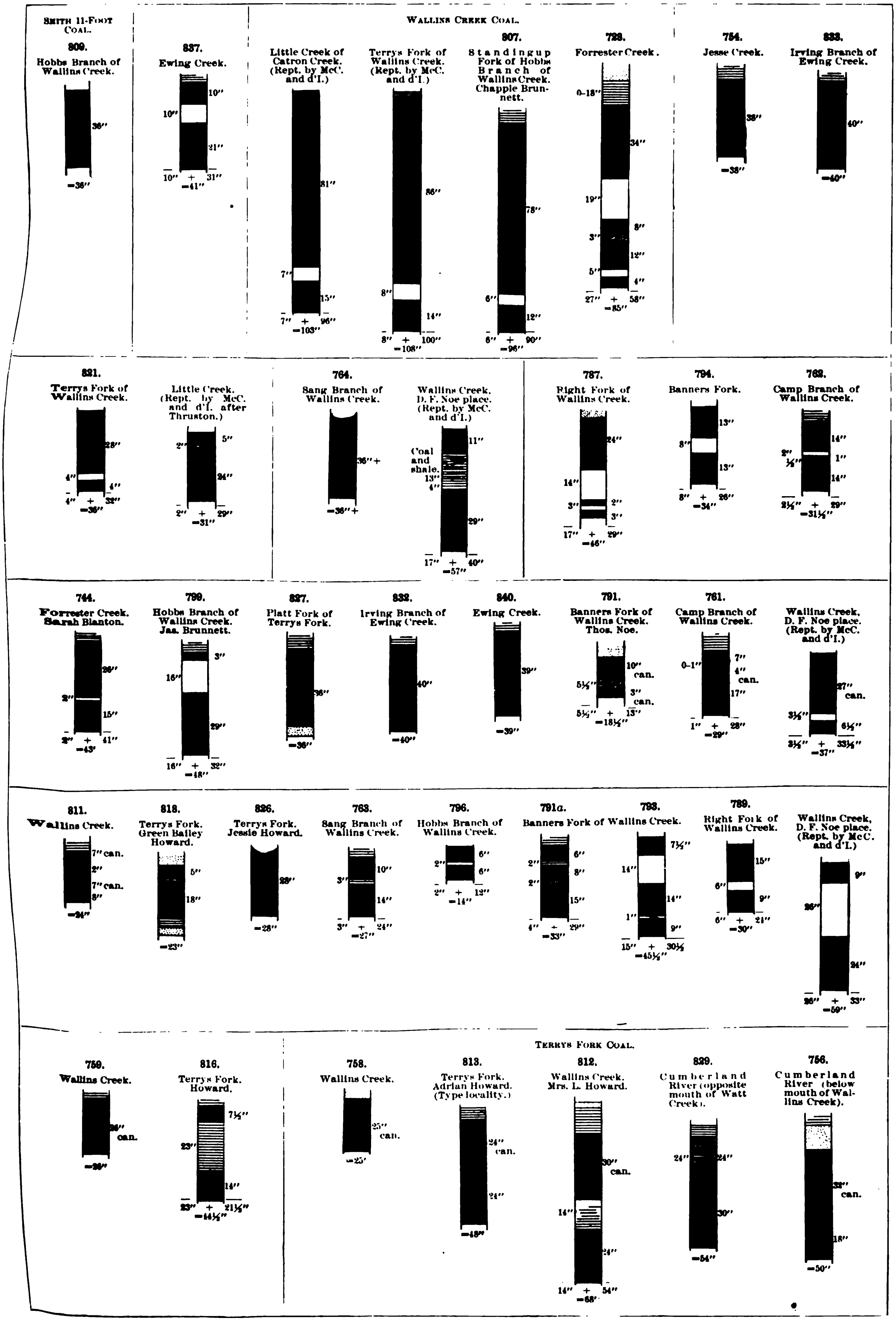
COALS.

COAL IN MINGO AND HANCE FORMATIONS.

Under this heading are first considered the coals above the Puckett sandstone. On Sang Branch of Wallins Creek, on the border of this district, Mr. David White found a 5-foot coal with three partings 100 feet below the Wallins Creek coal. He did not stop to examine it in detail. On Irving Branch of Ewing Creek at about the position of the Wallins Creek coal there were found two exposures of a 40-inch coal (833). These were not 30 feet apart horizontally, but one of them was 30 feet higher than the other. As the coals show the same measurement to an inch, it was thought a small fault came between them. No evidence of this fault could be found in the rocks outcropping just above. In about the same position on Jesse Creek a 38-inch solid coal was seen (754). On Little Creek McCreath and d'Invilliers report a small coal as follows:

"Beneath this [Wallins Creek coal] some hundred feet a lower coal showed 5 inches on top, 2 inches of bone parting, and 24 inches of bottom coal."

On Terrys Fork at about this elevation there was found a 32-inch coal (821), which showed a top bench of 28 inches separated from a bottom bench of 4 inches by 4 inches of clay. In some cases it was at first thought that this coal, ranging from 30 to 40 inches, was the representative of the Wallins Creek coal, especially where seen on Terrys Fork, Jesse Creek, and Irving Branch. Fuller consideration of the data, however, especially in view of the fact that the Wallins Creek coal has been reported to have a thickness of 9 feet on Terrys Fork, and that a 5-foot bed has been reported on Sang Branch 100 feet below the Wallins Creek coal, have led us to conclude that about 100 feet below the Wallins Creek coal there is a workable coal, but it has a thickness so little over the workable thickness that its value is questionable. The presence of this coal beneath the thick Wallins Creek coal in this district produced a certain resemblance between the manner of occurrence of the Smith 11-foot coal and of the 44-inch coal lying below it, and was one of the factors rendering doubtful our correlation of the 44-inch coal on Puckett Creek with the Wallins Creek coal and of the 11-foot coal with the 44-inch coal above the Wallins Creek coal on Trace Fork. In this case we have been influenced by the apparent relationship of the coals to the prominent cliff-making sandstones, so that the correlation that has been used is none too certain. One or two other coals were found locally above the Puckett sandstone and below the Wallins Creek coal. Of these, one on Ewing Creek (837) gave a total thickness of 41 inches, an upper bench of 10 inches, separated by 10 inches of clay from a lower bench of 21 inches. Below the Puckett sandstone in this district the principal problem was the recognition of the Harlan coal, which is such a valuable feature of the districts east and south of this one. Our efforts were not successful in finding a coal resembling the Harlan coal in thickness, or in its stratigraphic relationship to the rocks above or below it. The position at which we assigned the Harlan coal on the basis of the stratigraphy yielded no coal; either we were mistaken in the horizon which we correlated as Harlan, or the Harlan coal had run out in this district, or it exists and has not been exposed. On Forrester Creek a vein 43 inches thick, including a 2-inch parting 15 inches from the bottom (744), seems to occur at the stratigraphic position of the Harlan coal. Again, on Irving Branch of Ewing Creek at the horizon we assigned as that of the Harlan coal, a 7-foot coal was reported as having formerly been exposed, but is hidden now. In the districts east and south of this one a thick coal, though usually broken up with partings, called the Kellioka coal, lies about 250 feet above the Harlan coal. Coals were seen at two or three points in this district which were thought to possibly come at the horizon of the Kellioka coal. On Sang Branch of Wallins Creek just at the edge of the area (764) from 34 to 36 inches of coal were seen in a natural exposure. The top was not exposed, and it was reported that the total thickness of the coal here is 51 inches. On the D. F. Noe place, on a small branch entering Wallins Creek about one-fourth of a mile above the mouth of Banners Fork, Messrs. McCreath and d'Invilliers report a coal 400 feet above the creek that shows a total thickness of 4 feet 9 inches. However, the thickest bench, the bottom one, is only 2 feet 5 inches thick. Above it is 4 inches of shale, then 13 inches of coal and shale in 1-inch bands with an 11-inch bench of coal at the top. A short distance above the horizon which was considered that of the Harlan coal, thin coals were found at several places. On the right-hand fork of Wallins Creek this coal showed a top bench 24 inches thick, then 14 inches of clay, then 2 lower benches, 2 inches and 3 inches thick, separated by 3 inches of clay. The roof here is sandstone (787). On Banners Fork, at what was thought to be the same horizon, the coal showed two 13-inch benches separated by 8 inches of clay (794). On Camp Branch of Wallins Creek the coal at the same horizon shows a 14-inch bench at the top, then a parting of 3½ inches including a 1-inch band of coal one-half inch from the bottom, then a bottom bench of coal 14 inches thick (762). At an elevation of about 150 feet above the top of what was correlated in this region as the Cawood sandstone occurs a coal that in some locations is of a workable thickness. It is typically shown in the trail leading from Wallins Creek up Platt Fork of Terrys Fork and over to the Cumberland River. It is plainly exposed in the trail immediately above a thin bed of massive sandstone and is overlain by a thick bed of shale. At an entry a little to the west it measured 36 inches without partings (827). On Hobbs Branch of Wallins Creek what was thought to be the same coal has been opened on the James Brunnett place. The main bench gave a thickness of 29 inches of coal. Sixteen inches above that came a 3-inch bench of coal (799). On Irving Branch of Ewing Creek (833) apparently the same coal has been opened and shows a thickness of 3 feet 4 inches. As on Platt Fork of Terrys Fork (827), it immediately overlies a thin to massive sandstone and immediately underlies a considerable thickness of shales. On the main branch of Ewing Creek some distance above the mouth of Irving Branch the same coal has been opened and shows a thickness of 3 feet 3 inches (840). This coal was correlated with the cannel coal opened upon the Thomas Noe place, a short distance up Banners Fork of Wallins Creek on the north bank (791). The coal, however, shows a total thickness of only 13 inches of good coal, two benches—the upper 10 inches,


Smith 11-Foot Coal.
809.
Hobbs Branch of Wallins Creek.
36"
=36"
837.
Ewing Creek.
10"
10"
21"
10" + 31"
=41"
Wallins Creek Coal.
Little Creek of Catron Creek. (Rept. by McC. and d'I.)
81"
7"
15"
7" + 96"
=103"
Terrys Fork of Wallins Creek. (Rept. by McC. and d'I.)
86"
8"
14"
8" + 100"
=108"
807.
Standingup Fork of Hobbs Branch of Wallins Creek. Chapple Brunnett.
78"
6"
12"
6" + 90"
=96"
738.
Forrester Creek.
0-18"
34"
19"
8"
3"
12"
5"
4"
27" + 58"
=85"
754.
Jesse Creek.
38"
=38"
833.
Irving Branch of Ewing Creek.
40"
=40"
821.
Terrys Fork of Wallins Creek.
28"
4"
4"
4" + 32"
=36"
Little Creek. (Rept. by McC. and d'I. after Thruston.)
2"
5"
24"
2" + 29"
=31"
764.
Sang Branch of Wallins Creek.
36"+
=36"+
Wallins Creek. D. F. Noe place. (Rept. by McC. and d'I.)
11"
Coal and shale.
13"
4"
29"
17" + 40"
=57"
787.
Right Fork of Wallins Creek.
24"
14"
2"
3"
3"
17" + 29"
=46"
794.
Banners Fork.
13"
8"
13"
8" + 26"
=34"
762.
Camp Branch of Wallins Creek.
14"
2"
½"
1"
14"
2½" + 29"
=31½"
744.
Forrester Creek. Sarah Blanton.
26"
2"
15"
2" + 41"
=43"
799.
Hobbs Branch of Wallins Creek. Jas. Brunnett.
3"
16"
29"
16" + 32"
=48"
827.
Platt Fork of Terrys Fork.
36"
=36"
832.
Irving Branch of Ewing Creek.
40"
=40"
840.
Ewing Creek.
39"
=39"
791.
Banners Fork of Wallins Creek. Thos. Noe.
10" can.
5½"
3" can.
5½" + 13"
=18½"
761.
Camp Branch of Wallins Creek.
0-1"
7"
4" can.
17"
1" + 28"
=29"
Wallins Creek, D. F. Noe place. (Rept. by McC. and d'I.)
27" can.
3½"
6½"
3½" + 33½"
=37"
811.
Wallins Creek.
7" can.
2"
7" can.
8"
=24"
818.
Terrys Fork. Green Bailey Howard.
5"
18"
=23"
826.
Terrys Fork. Jessie Howard.
28"
=28"
763.
Sang Branch of Wallins Creek.
10"
3"
14"
3" + 24"
=27"
796.
Hobbs Branch of Wallins Creek.
2"
6"
6"
2" + 12"
=14"
791a.
Banners Fork of Wallins Creek.
2"
6"
2"
8"
15"
4" + 29"
=33"
793.
7½"
14"
14"
1"
9"
15" + 30½
=45½"
789.
Right Fork of Wallins Creek.
15"
6"
9"
6" + 24"
=30"
Wallins Creek, D. F. Noe place. (Rept. by McC. and d'I.)
9"
26"
24"
26" + 33"
=59"
759.
Wallins Creek.
26" can.
=26"
816.
Terrys Fork. Howard.
7½"
23"
14"
23" + 21½"
=44½"
Terrys Fork Coal.
758.
Wallins Creek.
25" can.
=25"
813.
Terrys Fork. Adrian Howard. (Type locality.)
24" can.
24"
=48"
812.
Wallins Creek. Mrs. L. Howard.
30" can.
14"
24"
14" + 54"
=68"
839.
Cumberland River (opposite mouth of Watt Creek).
24"
24"
30"
=54"
756.
Cumberland River (below mouth of Wallins Creek).
32" can.
18"
=50"

COAL SECTIONS, WALLINS CREEK DISTRICT.

Scale: 1 inch = 5 feet

total, 9 feet. The roof is of shale. A small 2-inch parting of splinty coal occurs about 6 inches above the fire clay, but its presence seems to have added but little if any to the percentage of ash as shown in the analyses of the coal from this place.

Analyses of this coal and two samples of its coke were obtained by Mr. Thruston at the head of Wallins Creek, and, though out of this district, will be included here to give a preliminary idea of the value of this coal as a coking coal. The section reported by him yielded a top bench 71 inches; coal and shale, 15 inches; clay, 7 inches; coal, 5 inches. On Sang Branch again this coal shows a very similar section to those already quoted. On Forrester Creek, the coal apparently at this horizon gives a total thickness of over 6 feet. It is rather badly broken up by partings, so as to be doubtfully workable. It shows a top bench of 34 inches, then 19 inches of clay, 8 inches of coal, 3 inches of bone, 12 inches of coal, 5 inches of clay, 4 inches of coal. There is a total of less than 5 feet of coal, and 34 inches is the thickest bench that could be worked. Over the coal is from 0 to 18 inches of shale below sandstone. Judging from the sections seen and those quoted on Little and Terrys branches, it would appear that this coal should be workable over nearly all of this district within its outcrop and over a large share of the district should present a single workable bench from 6 to 7 feet thick, not taking into consideration the bottom 12 to 15 inches below the fire clay parting. The following analyses will give some idea of its quality, though in the case of the sample obtained in 1902 and that obtained by Messrs. McCreath and d'Invilliers in 1888 the coal was very much weathered, yielding a high percentage of moisture and thereby reducing the percentage of combustible matter. The first of these analyses is by McCreath from a sample obtained in 1902 of coal on [illegible] Branch; the second analysis is by McCreath from a sample obtained by McCreath and d'Invilliers near the head of Terrys Fork; the third is by Robert Peter from a sample by R. C. B. Thruston of coal from the Milton Hensley place near the head of Wallins Creek. The fourth is of 48-hour coke made from the coal prepared for the third analysis. The fifth analysis is of 72-hour coke made from the same coal; the last two analyses are by Peter.

Analyses of Wallins Creek coal in Upper Puckett district.

Constituent.	A.	B	C.	D.	E
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	12.674	4.004	2.20	....	....
Volatile combustible matter	29.366	36.176	36.70	.60	0.90
Fixed carbon	48.805	53.611	58.86	93.10	92.90
Ash	7.630	5.590	2.24	6.30	6.20
Sulphur	.525	.619	.277	.546	.368

The coal, as shown by the above analyses, is low in sulphur, probably high in ash, contains on a fresh exposure probably a good percentage of combustible matter. It should therefore make a good steam coal, and from the analyses of the coke, it should yield a good coking coal. The sample obtained in 1902 was too much weathered to coke at all. The cokes, of which analyses are given, are [illegible] appearing to be good, firm, dense cokes.

COALS OF HIGNITE FORMATION.

Several coal blooms were seen on the flanks of Fox Knob in this formation. Of these, one (847) showed a heavy bloom suggesting the presence of a thick coal. The uppermost of these outcrops (844–845) was seen at three places, suggesting a persistent and possibly important coal. On the whole, these coals underlie such small areas as to be of little importance, even if of workable thickness.

SUMMARY.

Summary of coals of Wallins Creek district.

Number of coal beds found	30±
Total thickness of coals ... feet	20–30+
Number of coal beds of workable thickness	6±
Average thickness of principal workable coals ... feet	3 and 6
Greatest thickness of single coal bed measured ... do	8
Greatest thickness of coal measured in single bed ... do	$7\frac{1}{2}$
Estimated available tonnage of district ... tons	50,000,000

	Wallins Creek.	Other coals.
Approximate elevation ... feet above tide	2,500	...
Thickness:		
Greatest ... feet	9	...
Average ... do	$8\frac{1}{8}$	...
Least ... do	$7\frac{1}{12}$	...
Average thickness of workable coal ... do	6+	3+
Number of measurements	4	...
Area of seam ... acres	3,000	6,000
Total coal per acre ... tons	13,000	5,000
Available coal per acre ... do	8,000	4,000
Coal available in district ... do	24,000,000	24,000,000

STRUCTURE.

This basin is crossed near the center by the axis of the syncline. It crosses Forrester Creek well down toward the mouth approximately near the bench mark, 1,185 feet on the map. On Wallins Creek it crosses a short distance below the mouth of Camp Branch; on Ewing Creek about at the mouth of Irving Branch. On Wallins Creek to the north of the axis there is a sharp dip for a short distance showing in the shale and then to the mouth of the creek the rocks are approximately horizontal, though showing some local minor dips of some sharpness.

To the south of the axis of the syncline the dip keeps the rocks on Wallins Creek at just about the same vertical distance above creek level. Above Sang Branch the rise appears to be greater than the rise of the creek bed in going southward. On Ewing Creek south of the axis the rise appears to be quite sharp. The comparison of two sections from the creek to the crest of Wallins Ridge indicated, according to barometric readings, a dip to the south rather than in the opposite direction. Whether this difference is made up by faults, or whether there is an actual twisting of the rocks between the line of the creek and the line of the crest, or whether it was due to variation in barometric readings, could not be determined. At the mouth of Hobbs Branch the dip is to the east. At the mouth of Camp Branch the dip is quite strongly to the west, giving the appearance of an anticline along the valley of Wallins Creek. In general the dips are not very marked, with the result that the elevation of any coal or any sandstone layer does not vary much between the Cumberland River and the south limits of the district, in most cases probably not more than 100 to 300 feet at the outside.

HARLAN DISTRICT.

GEOGRAPHY.

This district includes portions of Big Black and Little Black mountains and the lower end of Ewings Spur. The mountains of this district are of the same general type as in the two districts last described. The coal of this district can be readily gotten at from Cumberland River or from any of its three forks. The coal in Big Black Mountain unfortunately dips into the mountain from both Poor Fork and Clover Fork sides. Were it possible to work this coal in a single body, it probably could be entered best from the extreme western end a short distance above the mouth of Poor Fork toward Harlan. The coal on Little Black Mountain can probably best be worked from Clover Fork, toward which it dips in the neighborhood of Harlan, though farther eastward there is a dip toward the east, making it desirable to attack the coal in that part of the mountain from Jones or Yocum creeks. The southern edge of this district lies nearly flat so that there the coals could be reached from the tributaries of Martins Fork. The coal in the end of Ewings Spur can possibly best be reached from Martins Fork more or less nearly opposite Harlan, as on the Cumberland River side it is dipping into the hill. Considering the elevation of the Harlan coal, which is the principal coal here, it is possible that it could be reached at its lowest point by means of low-level drifts carried in from Ages or English creeks or Middleton Branch farther east.

STRATIGRAPHY.

In this region, in contrast with the one last described, the lower portion of the stratigraphic column has been mainly depended upon for the correlation of the strata in the various portions of the field. The key rock in this case has been the Cawood sandstone. The Cawood sandstone outcrops in a small bluff at the top of the point immediately north of Harlan; from there it can be traced up Clover Fork, where it makes very prominent cliffs 100 feet or more high below Kitts Branch and opposite Lick Branch; it passes below stream level above Jones Creek. In like manner it can be fairly well traced around to Poor Fork and along the north flank of Big Black Mountain. South from Harlan it is not as distinct in this area on Martins Fork as it is below Turtle Creek. It makes bluffs on Martins Fork opposite Harlan and at other points along both banks of the fork; it reaches nearly to creek level at several points near Farmers and

Sections in Wallins Creek district—Continued.

ON TERRYS FORK OF WALLINS CREEK—Continued.

No. on map.	Stratum.	Thickness.	
		Ft.	*in.*
	Sandstone, thinly laminated, shaly	10	0
	Sandstone, gray, hard, flinty	1	6
	Sandstone, thinly laminated	5	0
	Shale, drab	8	0
	Sandstone, shaly	8	0
819	Coal	1	7+
	Sandstone, thinly laminated, to fissile shale	70	0
	Interval, hidden	10	0
	Sandstone, thinly laminated	10	0
	Interval, hidden	20	0
	Sandstone, massive, cross-bedded	20	0
	Interval, a 5-foot coal reported to be at this horizon could not be found	40	0
	Interval, position of Harlan coal	480	0
	Sandstone	5	0
	Shale	10	0
	Interval	100	0
	Sandstone	40	0
818	Coal	2	0
	Interval	50	0
	Sandstone, massive to thinly laminated, Cawood (?)	15	0
	Shale, drab	10	0
	Interval	130	0
817	Coal		4+
	Interval	30	0
814	Coal, Terrys Fork, type locality	4	0
	Interval	5	0
	Sandstone, Yellow Creek (?)	30	0

ON RIDGE BETWEEN EWING AND WALLINS CREEKS ON EWING CREEK SIDE.

	Interval	240	0
	Sandstone, coarse grained, Jesse (?)	30	0
	Interval	230	0
836	Coal		10
	Interval	15	0
837	Coal	2	7
	Interval	10	0
838	Coal	1	0
	Interval	60	0
839	Coal, covered, position of coal on Irving Branch (?)	3	4
	Interval	800	0
840	Coal, Ewing Creek	3	3
	Interval, to mouth of Ewing Creek	280	0

The section given next to this, on Pl. XXII, was obtained on a trip up Ewing Creek to the top of the mountain at Fox Knob, where a number of coal blooms occur near the top of the section. The last long section on the same plate was obtained on Little Creek of Catron Creek, the top of the section coming at Fox Knob and joining the section at the left. The difference in these two sections, particularly in the prominence of certain sandstones, illustrates very well the variability of the appearance of the rocks in outcrop and to a certain extent of the actual variation in the rocks. As the two sections are drawn, it is probable that the correlations are correctly shown. The lower of the two coals shown in this section appears to come at the horizon of the Wallins Creek coal, as that coal is exposed on Hobbs Branch and Banners Fork of Wallins Creek. The first massive sandstone below it then would appear to come at the position of the Slater sandstone rather than at the position of the Puckett sandstone, the latter having run out or become inconspicuous. The approximate position of the Harlan coal in the lower part of the section is suggested by known elevations of the Harlan coal a mile or two either side of this section.

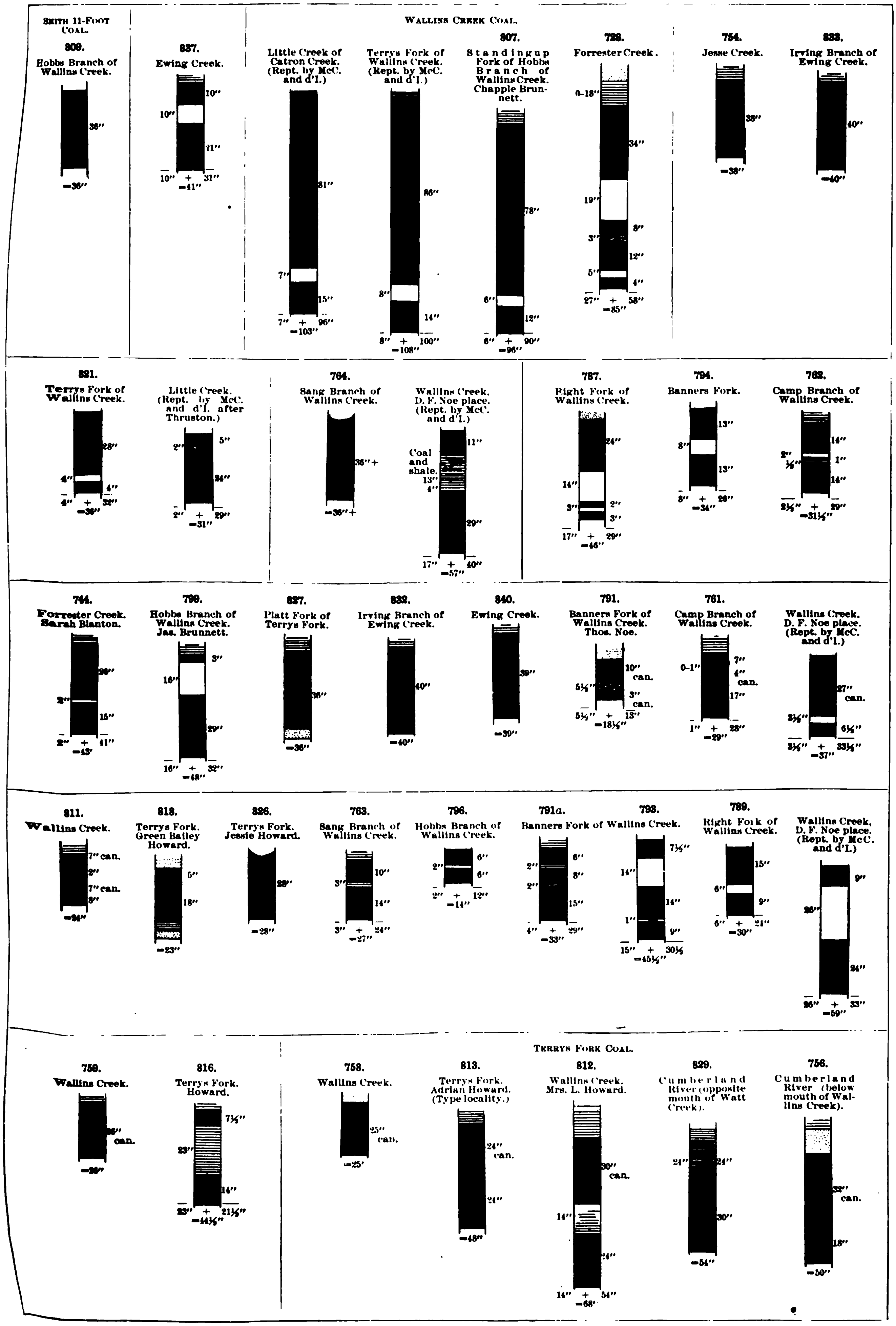
COALS.

COAL IN MINGO AND HANCE FORMATIONS.

Under this heading are first considered the coals above the Puckett sandstone. On Sang Branch of Wallins Creek, on the border of this district, Mr. David White found a 5-foot coal with three partings 100 feet below the Wallins Creek coal. He did not stop to examine it in detail. On Irving Branch of Ewing Creek at about the position of the Wallins Creek coal there were found two exposures of a 40-inch coal (833). These were not 30 feet apart horizontally, but one of them was 30 feet higher than the other. As the coals show the same measurement to an inch, it was thought a small fault came between them. No evidence of this fault could be found in the rocks outcropping just above. In about the same position on Jesse Creek a 38-inch solid coal was seen (754). On Little Creek McCreath and d'Invilliers report a small coal as follows:

"Beneath this [Wallins Creek coal] some hundred feet a lower coal showed 5 inches on top, 2 inches of bone parting, and 24 inches of bottom coal."

On Terrys Fork at about this elevation there was found a 32-inch coal (821), which showed a top bench of 28 inches separated from a bottom bench of 4 inches by 4 inches of clay. In some cases it was at first thought that this coal, ranging from 30 to 40 inches, was the representative of the Wallins Creek coal, especially where seen on Terrys Fork, Jesse Creek, and Irving Branch. Fuller consideration of the data, however, especially in view of the fact that the Wallins Creek coal has been reported to have a thickness of 9 feet on Terrys Fork, and that a 5-foot bed has been reported on Sang Branch 100 feet below the Wallins Creek coal, have led us to conclude that about 100 feet below the Wallins Creek coal there is a workable coal, but it has a thickness so little over the workable thickness that its value is questionable. The presence of this coal beneath the thick Wallins Creek coal in this district produced a certain resemblance between the manner of occurrence of the Smith 11-foot coal and of the 44-inch coal lying below it, and was one of the factors rendering doubtful our correlation of the 44-inch coal on Puckett Creek with the Wallins Creek coal and of the 11-foot coal with the 44-inch coal above the Wallins Creek coal on Trace Fork. In this case we have been influenced by the apparent relationship of the coals to the prominent cliff-making sandstones, so that the correlation that has been used is none too certain. One or two other coals were found locally above the Puckett sandstone and below the Wallins Creek coal. Of these, one on Ewing Creek (837) gave a total thickness of 41 inches, an upper bench of 10 inches, separated by 10 inches of clay from a lower bench of 21 inches. Below the Puckett sandstone in this district the principal problem was the recognition of the Harlan coal, which is such a valuable feature of the districts east and south of this one. Our efforts were not successful in finding a coal resembling the Harlan coal in thickness, or in its stratigraphic relationship to the rocks above or below it. The position at which we assigned the Harlan coal on the basis of the stratigraphy yielded no coal; either we were mistaken in the horizon which we correlated as Harlan, or the Harlan coal had run out in this district, or it exists and has not been exposed. On Forrester Creek a vein 43 inches thick, including a 2-inch parting 15 inches from the bottom (744), seems to occur at the stratigraphic position of the Harlan coal. Again, on Irving Branch of Ewing Creek at the horizon we assigned as that of the Harlan coal, a 7-foot coal was reported as having formerly been exposed, but is hidden now. In the districts east and south of this one a thick coal, though usually broken up with partings, called the Kellioka coal, lies about 250 feet above the Harlan coal. Coals were seen at two or three points in this district which were thought to possibly come at the horizon of the Kellioka coal. On Sang Branch of Wallins Creek just at the edge of the area (764) from 34 to 36 inches of coal were seen in a natural exposure. The top was not exposed, and it was reported that the total thickness of the coal here is 51 inches. On the D. F. Noe place, on a small branch entering Wallins Creek about one-fourth of a mile above the mouth of Banners Fork, Messrs. McCreath and d'Invilliers report a coal 400 feet above the creek that shows a total thickness of 4 feet 9 inches. However, the thickest bench, the bottom one, is only 2 feet 5 inches thick. Above it is 4 inches of shale, then 13 inches of coal and shale in 1-inch bands with an 11-inch bench of coal at the top. A short distance above the horizon which was considered that of the Harlan coal, thin coals were found at several places. On the right-hand fork of Wallins Creek this coal showed a top bench 24 inches thick, then 14 inches of clay, then 2 lower benches, 2 inches and 3 inches thick, separated by 3 inches of clay. The roof here is sandstone (787). On Banners Fork, at what was thought to be the same horizon, the coal showed two 13-inch benches separated by 8 inches of clay (794). On Camp Branch of Wallins Creek the coal at the same horizon shows a 14-inch bench at the top, then a parting of 3½ inches including a 1-inch band of coal one-half inch from the bottom, then a bottom bench of coal 14 inches thick (762). At an elevation of about 150 feet above the top of what was correlated in this region as the Cawood sandstone occurs a coal that in some locations is of a workable thickness. It is typically shown in the trail leading from Wallins Creek up Platt Fork of Terrys Fork and over to the Cumberland River. It is plainly exposed in the trail immediately above a thin bed of massive sandstone and is overlain by a thick bed of shale. At an entry a little to the west it measured 36 inches without partings (827). On Hobbs Branch of Wallins Creek what was thought to be the same coal has been opened on the James Brunnett place. The main bench gave a thickness of 29 inches of coal. Sixteen inches above that came a 3-inch bench of coal (799). On Irving Branch of Ewing Creek (833) apparently the same coal has been opened and shows a thickness of 3 feet 4 inches. As on Platt Fork of Terrys Fork (827), it immediately overlies a thin to massive sandstone and immediately underlies a considerable thickness of shales. On the main branch of Ewing Creek some distance above the mouth of Irving Branch the same coal has been opened and shows a thickness of 3 feet 3 inches (840). This coal was correlated with the cannel coal opened upon the Thomas Noe place, a short distance up Banners Fork of Wallins Creek on the north bank (791). The coal, however, shows a total thickness of only 13 inches of good coal, two benches—the upper 10 inches,


SMITH 11-FOOT COAL.
809. Hobbs Branch of Wallins Creek.
36"
=36"
837. Ewing Creek.
10"
10"
21"
10" + 31" =41"
WALLINS CREEK COAL.
Little Creek of Catron Creek. (Rept. by McC. and d'I.)
81"
7"
15"
7" + 96" =103"
Terrys Fork of Wallins Creek. (Rept. by McC. and d'I.)
86"
8"
14"
8" + 100" =108"
807. Standingup Fork of Hobbs Branch of Wallins Creek. Chapple Brunnett.
78"
6"
12"
6" + 90" =96"
728. Forrester Creek.
0-18"
34"
19"
8"
3"
12"
5"
4"
27" + 58" =85"
754. Jesse Creek.
38"
=38"
833. Irving Branch of Ewing Creek.
40"
=40"
831. Terrys Fork of Wallins Creek.
28"
4"
4"
4" + 32" =36"
Little Creek. (Rept. by McC. and d'I. after Thruston.)
2"
5"
24"
2" + 29" =31"
764. Sang Branch of Wallins Creek.
36"+
=36"+
Wallins Creek. D. F. Noe place. (Rept. by McC. and d'I.)
11"
Coal and shale. 13"
4"
29"
17" + 40" =57"
787. Right Fork of Wallins Creek.
24"
14"
3"
2"
3"
17" + 29" =46"
794. Banners Fork.
13"
8"
13"
8" + 26" =34"
762. Camp Branch of Wallins Creek.
14"
2"
½"
1"
14"
2½" + 29" =31½"
744. Forrester Creek. Sarah Blanton.
26"
2"
15"
2" + 41" =43"
799. Hobbs Branch of Wallins Creek. Jas. Brunnett.
3"
16"
29"
16" + 32" =48"
827. Platt Fork of Terrys Fork.
36"
=36"
832. Irving Branch of Ewing Creek.
40"
=40"
840. Ewing Creek.
39"
=39"
791. Banners Fork of Wallins Creek. Thos. Noe.
10" can.
5½"
3" can.
5½" + 13" =18½"
761. Camp Branch of Wallins Creek.
0-1"
7"
4" can.
17"
1" + 28" =29"
Wallins Creek. D. F. Noe place. (Rept. by McC. and d'I.)
27" can.
3½"
6½"
3½" + 33½" =37"
811. Wallins Creek.
7" can.
2"
7" can.
8"
=24"
818. Terrys Fork. Green Bailey Howard.
5"
18"
=23"
826. Terrys Fork. Jessie Howard.
28"
=28"
763. Sang Branch of Wallins Creek.
10"
3"
14"
3" + 24" =27"
796. Hobbs Branch of Wallins Creek.
2"
6"
6"
2" + 12" =14"
791a. Banners Fork of Wallins Creek.
2"
6"
2"
8"
15"
4" + 29" =33"
793.
7½"
14"
14"
1"
9"
15" + 30½ =45½"
789. Right Fork of Wallins Creek.
15"
6"
9"
6" + 24" =30"
Wallins Creek, D. F. Noe place. (Rept. by McC. and d'I.)
9"
26"
24"
26" + 33" =59"
759. Wallins Creek.
26" can.
=26"
816. Terrys Fork. Howard.
7½"
23"
14"
23" + 21½" =44½"
TERRYS FORK COAL.
758. Wallins Creek.
25" can.
=25"
813. Terrys Fork. Adrian Howard. (Type locality.)
24" can.
24"
=48"
812. Wallins Creek. Mrs. L. Howard.
30" can.
14"
24"
14" + 54" =68"
829. Cumberland River (opposite mouth of Watt Creek).
24"
24"
30"
=54"
756. Cumberland River (below mouth of Wallins Creek).
32" can.
18"
=50"

COAL SECTIONS, WALLINS CREEK DISTRICT.

Scale 1 inch=5 feet.

and the type locality is on the Adrian Howard place, just below the mouth of Platt Fork of Terrys Fork (813). Quite a number of openings have been made upon the coal between the mouth of Platt Fork and the mouth of Terrys Fork. Where it is being mined the coal showed a total thickness of 4 feet, of which the upper bench was cannel and the lower bituminous coal. Around the divide between Terrys Fork and Wallins Creek, on the Wallins Creek side, on Mrs. L. Howard's place, apparently the same coal has been opened, showing a total thickness of coal of 54 inches. It is in two benches, as before, the upper bench, 30 inches thick, being bituminous, but at this point (812) the two benches are separated by 14 inches of clay and shale. Apparently the same coal is again found on the Cumberland River about 30 feet above low-water level, showing a bottom bench 30 inches thick and a top bench 24 inches thick, though in this case the top bench is much more shaly than at the type locality, and a large share of it would be classed as bituminous shale rather than as a cannel coal. A little farther up Wallins Creek, above Mrs. Howard's, this coal has been opened or faced at several points, showing in most of these cases about 2 feet of coal (758). It is very close to and finally passes under water level. Below the mouth of Wallins Creek on the trail passing over the end of the ridge to Jesse Creek, the coal has been opened, showing 32 inches of bony coal in the upper bench and 18 inches of bituminous coal in the lower bench (756). This last exposure of the coal is so far above the lower creek sandstone, as correlated, that it can only doubtfully be referred to the same horizon as the coal on Terrys Fork. On Terrys Fork another coal a short distance above the 4-foot coal shows at several points and at (816) yielded two benches—the lower 14 inches, the upper 7½ inches—separated by 23 inches of shale. On Wallins Creek a 26-inch cannel coal shows about 20 feet above the Terrys Fork coal. The roof of the lower of these two coals is usually a shale, but in many places a sandstone. The sandstone is very irregular in some cases, sometimes lying immediately upon the coal with a massive thickness of 5 or 6 feet, while a few yards away it has entirely feathered out and only shale shows above the coal. The following analyses of the Terrys Fork coal show the quality of the seam as a whole, and of the cannel and bituminous parts separately:

Analyses of Terrys Fork coal.

Constituent.	A.	B.	C.	D.	E.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	1.120	0.90	0.796	0.90	1.252
Volatile hydrocarbons	37.390	30.10	33.364	34.30	37.583
Fixed carbons	47.774	42.40	35.872	62.50	57.499
Ash	12.800	26.60	29.345	2.30	2.270
Sulphur	.916	.084	.683	.577	1.396

A. Whole seam; sample taken in 1902.
B. Upper or cannel bench; analysis by Peter, sample obtained by R. C. B. Thruston.
C. Same bench; analysis by McCreath, sample collected by McCreath and d'Invilliers.
D. Lower bench of bituminous; analysis by Peter, sample obtained by R. C. B. Thruston in 1887.
E. Same bench; analysis by McCreath, sample obtained by McCreath and d'Invilliers.

total, 9 feet. The roof is of shale. A small 2-inch parting of splinty coal occurs about 6 inches above the fire clay, but its presence seems to have added but little if any to the percentage of ash as shown in the analyses of the coal from this place.

Analyses of this coal and two samples of its coke were obtained by Mr. Thruston at the head of Wallins Creek, and, though out of this district, will be included here to give a preliminary idea of the value of this coal as a coking coal. The section reported by him yielded a top bench 71 inches; coal and shale, 15 inches; clay, 7 inches; coal, 5 inches. On Sang Branch again this coal shows a very similar section to those already quoted. On Forrester Creek, the coal apparently at this horizon gives a total thickness of over 6 feet. It is rather badly broken up by partings, so as to be doubtfully workable. It shows a top bench of 34 inches, then 19 inches of clay, 8 inches of coal, 3 inches of bone, 12 inches of coal, 5 inches of clay, 4 inches of coal. There is a total of less than 5 feet of coal, and 34 inches is the thickest bench that could be worked. Over the coal is from 0 to 18 inches of shale below sandstone. Judging from the sections seen and those quoted on Little and Terrys branches, it would appear that this coal should be workable over nearly all of this district within its outcrop and over a large share of the district should present a single workable bench from 6 to 7 feet thick, not taking into consideration the bottom 12 to 15 inches below the fire-clay parting. The following analyses will give some idea of its quality, though in the case of the sample obtained in 1902 and that obtained by Messrs. McCreath and d'Invilliers in 1888 the coal was very much weathered, yielding a high percentage of moisture and thereby reducing the percentage of combustible matter. The first of these analyses is by McCreath from a sample obtained in 1902 of coal on Hobbs Branch; the second analysis is by McCreath from a sample obtained by McCreath and d'Invilliers near the head of Terrys Fork; the third is by Robert Peter from a sample by R. C. B. Thruston of coal from the Milton Hensley place near the head of Wallins Creek. The fourth is of 48-hour coke made from the coal procured for the third analysis. The fifth analysis is of 72-hour coke made from the same coal; the last two analyses are by Peter.

Analyses of Wallins Creek coal in Upper Puckett district.

Constituent.	A.	B	C.	D.	E.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent*
Moisture	12.674	4.004	2.20	....	....
Volatile hydrocarbons	29.366	36.176	36.70	.60	0.90
Fixed carbon	48.805	53.611	58.86	93.10	92.90
Ash	7.630	5.590	2.24	6.30	6.20
Sulphur	.525	.619	.277	.546	.368

This coal, as shown by the above analyses, is low in sulphur, probably high in ash, and contains on a fresh exposure probably a good percentage of combustible matter. It should therefore make a good steam coal, and from the analyses of the cokes given may yield a good coking coal. The sample obtained in 1902 was too badly weathered to coke at all. The cokes, of which analyses are given, are described as appearing to be good, firm, dense cokes.

COALS OF HIGNITE FORMATION.

Several coal blooms were seen on the flanks of Fox Knob in this formation. Of these, one (847) showed a heavy bloom suggesting the presence of a thick coal. The uppermost of these outcrops (844–845) was seen at three places, suggesting a persistent and possibly important coal. On the whole, these coals underlie such small areas as to be of little importance, even if of workable thickness.

SUMMARY.

Summary of coals of Wallins Creek district.

Number of coal beds found		30±
Total thickness of coals	feet	20–30+
Number of coal beds of workable thickness		6±
Average thickness of principal workable coals	feet	3 and 6
Greatest thickness of single coal bed measured	do	8
Greatest thickness of coal measured in single bed	do	7½
Estimated available tonnage of district	tons	50,000,000

		Wallins Creek.	Other coals.
Approximate elevation	feet above tide	2,500	....
Thickness:			
Greatest	feet	9	....
Average	do	8⅛	....
Least	do	$7\frac{1}{12}$	....
Average thickness of workable coal	do	6+	3+
Number of measurements		4	....
Area of seam	acres	3,000	6,000
Total coal per acre	tons	13,000	5,000
Available coal per acre	do	8,000	4,000
Coal available in district	do	24,000,000	24,000,000

STRUCTURE.

This basin is crossed near the center by the axis of the syncline. It crosses Forrester Creek well down toward the mouth approximately near the bench mark, 1,185 feet on the map. On Wallins Creek it crosses a short distance below the mouth of Camp Branch; on Ewing Creek about at the mouth of Irving Branch. On Wallins Creek to the north of the axis there is a sharp dip for a short distance showing in the shale and then to the mouth of the creek the rocks are approximately horizontal, though showing some local minor dips of some sharpness.

To the south of the axis of the syncline the dip keeps the rocks on Wallins Creek at just about the same vertical distance above creek level. Above Sang Branch the rise appears to be greater than the rise of the creek bed in going southward. On Ewing Creek south of the axis the rise appears to be quite sharp. The comparison of two sections from the creek to the crest of Wallins Ridge indicated, according to barometric readings, a dip to the south rather than in the opposite direction. Whether this difference is made up by faults, or whether there is an actual twisting of the rocks between the line of the creek and the line of the crest, or whether it was due to variation in barometric readings, could not be determined. At the mouth of Hobbs Branch the dip is to the east. At the mouth of Camp Branch the dip is quite strongly to the west, giving the appearance of an anticline along the valley of Wallins Creek. In general the dips are not very marked, with the result that the elevation of any coal or any sandstone layer does not vary much between the Cumberland River and the south limits of the district, in most cases probably not more than 100 to 300 feet at the outside.

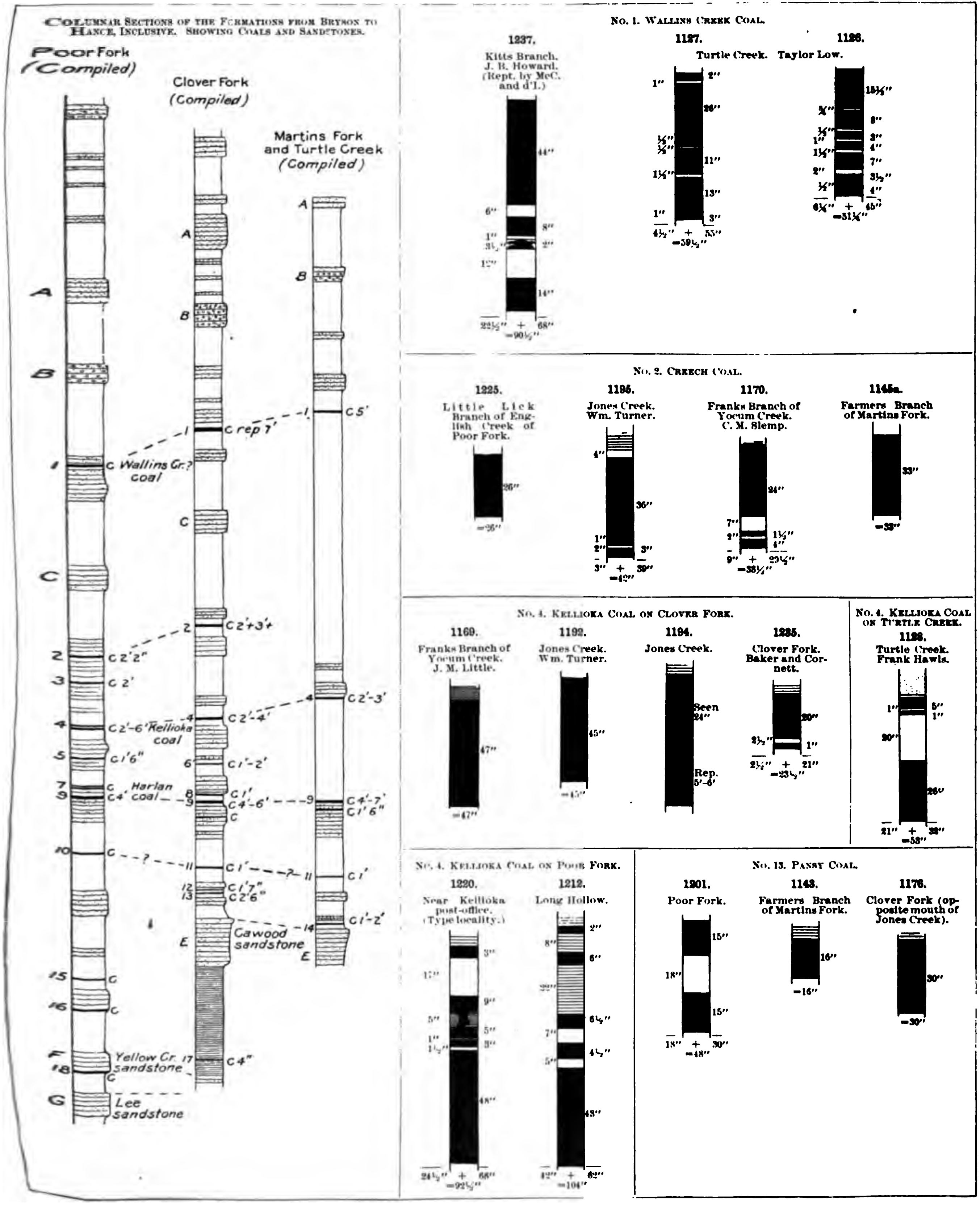
HARLAN DISTRICT.

GEOGRAPHY.

This district includes portions of Big Black and Little Black mountains and the lower end of Ewings Spur. The mountains of this district are of the same general type as in the two districts last described. The coal of this district can be readily gotten at from Cumberland River or from any of its three forks. The coal in Big Black Mountain unfortunately dips into the mountain from both Poor Fork and Clover Fork sides. Were it possible to work this coal in a single body, it probably could be entered best from the extreme western end a short distance above the mouth of Poor Fork toward Harlan. The coal on Little Black Mountain can probably best be worked from Clover Fork, toward which it dips in the neighborhood of Harlan, though farther eastward there is a dip toward the east, making it desirable to attack the coal in that part of the mountain from Jones or Yocum creeks. The southern edge of this district lies nearly flat so that there the coals could be reached from the tributaries of Martins Fork. The coal in the end of Ewings Spur can possibly best be reached from Martins Fork more or less nearly opposite Harlan, as on the Cumberland River side it is dipping into the hill. Considering the elevation of the Harlan coal, which is the principal coal here, it is possible that it could be reached at its lowest point by means of low-level drifts carried in from Ages or English creeks or Middleton Branch farther east.

STRATIGRAPHY.

In this region, in contrast with the one last described, the lower portion of the stratigraphic column has been mainly depended upon for the correlation of the strata in the various portions of the field. The key rock in this case has been the Cawood sandstone. The Cawood sandstone outcrops in a small bluff at the top of the point immediately north of Harlan; from there it can be traced up Clover Fork, where it makes very prominent cliffs 100 feet or more high below Kitts Branch and opposite Lick Branch; it passes below stream level above Jones Creek. In like manner it can be fairly well traced around to Poor Fork and along the north flank of Big Black Mountain. South from Harlan it is not as distinct in this area on Martins Fork as it is below Turtle Creek. It makes bluffs on Martins Fork opposite Harlan and at other points along both banks of the fork; it reaches nearly to creek level at several points near Farmers and


Columnar Sections of the Formations from Bryson to Hance, Inclusive. Showing Coals and Sandstones.
Poor Fork (Compiled)
Clover Fork (Compiled)
Martins Fork and Turtle Creek (Compiled)
A
B
C
C Wallins Cr.? coal
C rep 7'
C 5'
C 2'2"
C 2'
C 2'+3'+
C 2'-4'
C 2'-3'
C 2'-6' Kellioka coal
C 1'6"
C 1'-2'
C Harlan C 4' coal
C 1' C 4'-6' C
C 4'-7' C 1'6"
C 1'
C 1'7" C 2'6"
C 1'-2'
Cawood sandstone
E
F Yellow Cr. sandstone
C 4"
G Lee sandstone
No. 1. Wallins Creek Coal.
1237. Kitts Branch. J. B. Howard. (Rept. by McC. and d'I.)
22½" + 68" =90½"
1127. Turtle Creek.
4½" + 55" =59½"
1126. Taylor Low.
6¼" + 45" =51¼"
No. 2. Creech Coal.
1225. Little Lick Branch of English Creek of Poor Fork.
=26"
1195. Jones Creek. Wm. Turner.
3" + 39" =42"
1170. Franks Branch of Yocum Creek. C. M. Slemp.
9" + 29½" =38¼"
1145a. Farmers Branch of Martins Fork.
=33"
No. 4. Kellioka Coal on Clover Fork.
1169. Franks Branch of Yocum Creek. J. M. Little.
=47"
1192. Jones Creek. Wm. Turner.
=45"
1194. Jones Creek.
Seen 24"
Rep. 5'-6'
1235. Clover Fork. Baker and Cornett.
2½" + 21" =23½"
No. 4. Kellioka Coal on Turtle Creek.
1128. Turtle Creek. Frank Hawls.
21" + 32" =53"
No. 4. Kellioka Coal on Poor Fork.
1220. Near Kellioka post-office. (Type locality.)
24½" + 68" =92½"
1212. Long Hollow.
42" + 62" =104"
No. 13. Pansy Coal.
1201. Poor Fork.
18" + 30" =48"
1143. Farmers Branch of Martins Fork.
=16"
1176. Clover Fork (opposite mouth of Jones Creek).
=30"

COLUMNAR AND COAL SECTIONS, HARLAN DISTRICT.

Scales: Columnar sections, 1 inch=300 feet; coal sections, 1 inch=5 feet. (For Harlan coal No. 9 see Pl. 25, p. 160.)

Coal, Kellioka	2–6	0
Interval	60	0
Coal	1	6
Interval	70	0
Coal	......	
Interval	30	0
Coal, Harlan	4	0
Interval	110	0
Coal	......	
Interval	80	0
Sandstone, cliff making, Cawood?	50	0
Interval	140	0
Coal	......	
Interval	20	0
Sandstone, cliff making	50	0
Coal	......	
Interval	90	0
Sandstone, Yellow Creek	50	0
Coal	......	
Interval to top of massive sandstone	40	0

As the rocks along Poor Fork in many cases have dips of 30° to 40°, it has been found a little difficult to correlate the different sections, so the above general section is largely hypothetical. The section from the 26-inch coal to the Harlan coal was mainly obtained from Little Lick Branch of English Creek, except that the Kellioka coal, if exposed at all in this section, is represented by a 2-foot coal. The exposure there is clean, showing mainly sandstones.

On Clover Fork no high dips are met with and the section can be compiled with much more certainty. The intervals between most of the members and the thicknesses of the coals found are as follows:

Skeleton section of upper members and coals on Clover Fork (compiled).

	Ft.	In.
Sandstone, Reynolds	70	0
Interval	120	0
Sandstone, coarse grained, Jesse	40	0
Interval, computed	220	0
Coal, Wallins Creek?	7	0
Interval	40	0
Sandstone, Puckett?	30	0
Interval	110	0
Sandstone, Slater?	50	0
Interval	200	0
Coal	2–3	0
Interval	200	0
Coal, Kellioka	2–4	0
Interval	100	0
Coal	1–2	0
Interval	30	0
Coal	1	0
Interval	20	0
Coal, Harlan	4–6	0
Interval	30	0
Coal, bloom	....	

coal, which locally is of good workable thickness; and the Harlan coal, which alone makes this region one of great promise. Below the Harlan coal were seen a few outcrops of coals, which in one or two places were of workable thickness. In this and in the Martins Fork and Upper Puckett districts the Harlan coal has been traced almost continuously by openings where sections can be measured, usually not over 3 or 4 miles apart.

COAL OF HANCE FORMATION.

In this district almost no coal of workable thickness was found below the Harlan coal. The best exposure was on Clover Fork, nearly opposite the mouth of Jones Creek (1176). The coal here showed a thickness of 30 inches, with a shale roof. A large number of points gave coals of from 1 foot to 18 inches. On the whole, the evidence did not bear out the idea that in the presence of the Harlan bed any of the coal below will be worked or may be considered as workable.

COALS OF MINGO FORMATION.

HARLAN COAL.

For a type locality of this coal bed we may take the Green Jones bank, or the Baker and Cornett, or the G. A. S. Kelly banks, all of which are just across Clover Fork from Harlan and all of which are upon the same seam. At the Green Jones bank (1162) there are several old openings from which the coal has been worked for some time. The coal shows an upper bench of from 3 feet 10 inches to 4 feet 4 inches. This bench alone is worked. Seven inches lower, the parting being shale, is a lower bench which runs from 12 to 14 inches thick. Over the coal is 1 inch of shale, then 1 inch of bony coal with shale roof above; 5 or 6 inches of the roof is draw slate, which does not always come down; 5 feet above the coal are 12 feet or more of massive sandstone. The lower bench would be taken out in entries. On the Baker and Cornett place (1164), which is but a short distance from the former, the coal shows almost exactly the same conditions of thickness and parting. The parting here is soft clay; the roof (shale) is 10 feet thick and good. A few inches tend to come down in spots. It is said that only an occasional plate of pyrite is met with in the mine. The floor is hard. At the G. A. S. Kelly opening (1165) the top bench is 4 feet 3 inches thick, the clay parting has thickened up to 13 inches, and there is 14 inches of bottom coal. The top 3 inches of coal is dry and splinty; above the coal are 6 inches of black shale, and from 1 to 2 inches of coal, 6 inches of black shale, and 4 feet of clay shale to the bottom of a massive sandstone. The lower bench here is not mined. The coal is reported very hard, being shot on the solid as a rule, it is sometimes undercut for a foot or two. Butts run S. 40° W. The roof is a soft, spongy shale, which tends to fall on weathering. It has generally been believed in this region that about 100 feet lower is another coal 4 feet thick. This belief seems to be based on the fact that on the north side of Clover Fork the Harlan coal has no bottom bench, or else the bottom bench is so far separated from the main bench as not to be distinguished, while the general dip into Big Black Mountain has carried the coal 100 feet lower.

English Creek
inches of
that. For
Branch of
with 1— feet
feet thick and
(202) a poorly
this place that 90

feet above was a 6-foot coal, with 8 inches of shale 4 feet from the top. This was said to be the Green Jones coal. We are inclined to think again that this was purely an inference from the supposed relationship of the Harlan coal as exposed on the two sides of Clover Fork. It has 20 feet of shale above and 50 feet of massive sandstone beneath. One opening on this coal was found on the nose of Ewing Spur, which extends into this district (1233). The coal here showed a thickness of 46 inches without partings, and has a sandy shale roof. It is approximately 430 feet above Cumberland River. On the north side of Clover Fork the first opening above Harlan is on the Turner place (1198). The coal shows a thickness of 4 feet without partings; the roof is composed of 10 feet of clay shale overlain by massive sandstone. Below the coal are from 8 to 18 inches of clay and sandstone, indicating that the lower bench on the south side of Clover Fork is entirely wanting here. The coal is approximately 250 feet above the Cawood sandstone; it agrees in this respect with the coal at the Green Jones opening, and at most of the openings seen in this and the two districts next described. Several openings made at this point show that the coal dips rapidly to the northwest into Big Black Mountain. Between the extreme openings there is a dip of probably 40 feet, and the northernmost entry had to be abandoned on account of the water accumulating at the face. In the next ravine to the east, in an opening on the James Huff place (1188), the coal shows a thickness of 46 inches, including 1 inch of bone and coal 3 inches from the top. There are here only 3 inches of shale between the coal and the massive sandstone roof. On the Sherman Farmer place (1185) this seam shows 4 feet of solid coal with shaly sandstone roof. The roof appears to be hard, though from 1 to 6 inches come down in the entry. The floor is drab fire clay, appearing to be soft where wet. The coal at this point is lowered to the road by a chute having 370 feet vertical fall. On the Jesse Gilbert place (1183) the coal is 4 feet 2 inches thick without partings, and is immediately overlain by 25+ feet of massive sandstone. There is about 50 feet of massive sandstone close beneath it. Traces of coal were found about 30 feet below which suggested the possibility that the lower bench on the south side of Clover Fork might have become separated from the main bench by that distance. On the Harris place (1181) 3 feet 4 inches of coal were seen, the bottom not being exposed. There are here 2 feet of clay shale between the coal and the shaly massive sandstone above. Two openings have been made on Ages Creek. At the Lloyd Ball opening (1197) 42 inches of coal were seen, over 8 inches of fire clay, and 15 feet of shale. At the John Grill place, on the left-hand fork (1198), the seam showed 45 inches of coal over 7 inches of badly weathered splinty coal; 3 feet of shale come above the coal, and 8 inches of clay come between the coal and the sandstone floor. At the W. M. Smith place (1180) the coal shows a thickness of 4 feet 3 inches with 2½ inches of bone 7½ inches from the top. The roof here seems good, being composed of 4 feet of shale under a brown sandstone; 3 inches of it may come down, and the 6 inches above that has a clay streak at the top that in places may soften letting that additional 6 inches down. The floor is a blue clay and solid. The coal in the mine appears dry, bright, and fine. The faces run N. 35° W. On the Sam Middleton place (1179) the bed has a total thickness of 4 feet 8 inches, but here shows two partings, a 1-inch parting 14

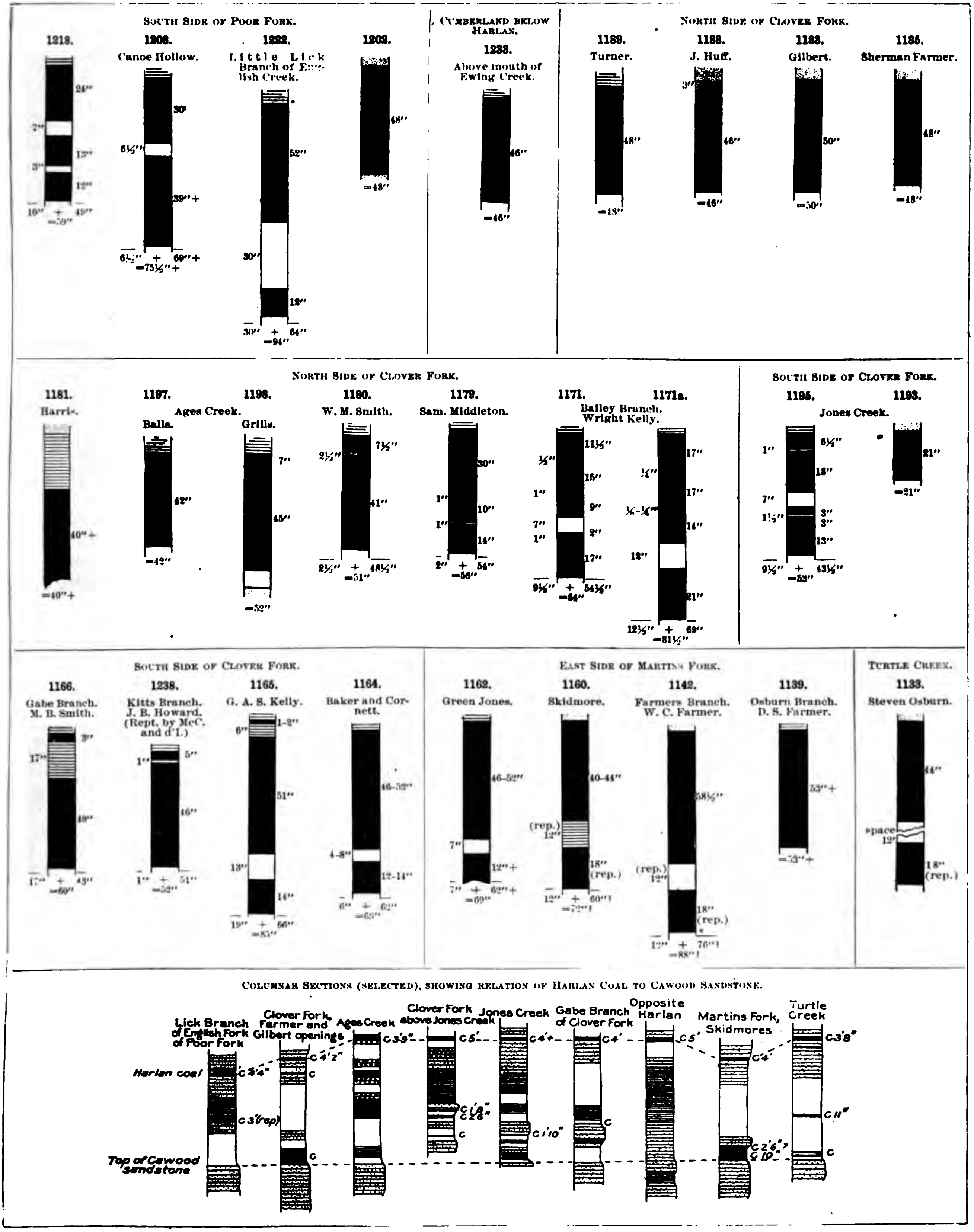
Coal, Kellioka	2–6	0
Interval	60	0
Coal	1	6
Interval	70	0
Coal	-----	
Interval	30	0
Coal, Harlan	4	0
Interval	110	0
Coal	-----	
Interval	80	0
Sandstone, cliff making, Cawood?	50	0
Interval	140	0
Coal	-----	
Interval	20	0
Sandstone, cliff making	50	0
Coal	-----	
Interval	90	0
Sandstone, Yellow Creek	50	0
Coal	-----	
Interval to top of massive sandstone	40	0

As the rocks along Poor Fork in many cases have dips of 30° to 40°, it has been found a little difficult to correlate the different sections, so the above general section is largely hypothetical. The section from the 26-inch coal to the Harlan coal was mainly obtained from Little Lick Branch of English Creek, except that the Kellioka coal, if exposed at all in this section, is represented by a 2-foot coal. The exposure there is clean, showing mainly sandstones.

On Clover Fork no high dips are met with and the section can be compiled with much more certainty. The intervals between most of the members and the thicknesses of the coals found are as follows:

Skeleton section of upper members and coals on Clover Fork (compiled).

	Ft.	in.
Sandstone, Reynolds	70	0
Interval	120	0
Sandstone, coarse grained, Jesse	40	0
Interval, computed	220	0
Coal, Wallins Creek?	7	0
Interval	40	0
Sandstone, Puckett?	30	0
Interval	110	0
Sandstone, Slater?	50	0
Interval	200	0
Coal	2–3	0
Interval	200	0
Coal, Kellioka	2–4	0
Interval	100	0
Coal	1–2	0
Interval	30	0
Coal	1	0
Interval	20	0
Coal, Harlan	4–6	0
Interval	30	0
Coal, bloom	--------	


South Side of Poor Fork.
1218.
1206. Canoe Hollow.
1222. Little Lick Branch of English Creek.
1202.
Cumberland below Harlan.
1233. Above mouth of Ewing Creek.
North Side of Clover Fork.
1189. Turner.
1188. J. Huff.
1183. Gilbert.
1185. Sherman Farmer.
1181. Harris.
North Side of Clover Fork.
Ages Creek.
1197. Balls.
1198. Grills.
1180. W. M. Smith.
1179. Sam. Middleton.
1171. 1171a. Bailey Branch. Wright Kelly.
South Side of Clover Fork.
1195. 1193. Jones Creek.
South Side of Clover Fork.
1166. Gabe Branch. M. B. Smith.
1238. Kitts Branch. J. B. Howard. (Rept. by McC. and d'I.)
1165. G. A. S. Kelly.
1164. Baker and Cornett.
East Side of Martins Fork.
1162. Green Jones.
1160. Skidmore.
1142. Farmers Branch. W. C. Farmer.
1139. Osburn Branch. D. S. Farmer.
Turtle Creek.
1133. Steven Osburn.
Columnar Sections (selected), showing relation of Harlan Coal to Cawood Sandstone.
Lick Branch of English Fork of Poor Fork
Clover Fork, Farmer and Gilbert openings
Ages Creek
Clover Fork above Jones Creek
Jones Creek
Gabe Branch of Clover Fork
Opposite Harlan
Martins Fork, Skidmores
Turtle Creek
Harlan coal
Top of Cawood sandstone

SECTIONS OF HARLAN COAL AND COLUMNAR SECTIONS, HARLAN DISTRICT.

Scales: Columnar sections, 1 inch=300 feet; coal sections, 1 inch=5 feet

Interval	110	0
Coal	1	0
Interval	40	0
Coal	1	7
Interval	10	0
Coal	2	6
Interval	60	0
Sandstone, Cawood	20–100	0
Interval, shale	240	0
Sandstone in bed of Clover Fork at Harlan		

The following detailed section will give a better idea of the rocks immediately above and below the Harlan coal. It was obtained in the Bakers Branch of Clover Fork just southeast of Harlan:

Section in Baker Branch.

No. on map.	Stratum.	Thickness.		No. on map.	Stratum.	Thickness.	
		Ft.	*in.*			*Ft.*	*in.*
	Sandstone, massive	20+	0		Shale, drab	5	0
	Interval, hidden	10	0	1236	Coal		11
	Clay shale to sandy shale	25	0		Fire clay, drab	1	0
	Shale, black	1	0		Sandstone	2	0
1235	Coal	1	8		Shale	3	0
	Clay, drab		2½		Sandstone, massive, cross-bedded	45	0
	Coal		1		Shale, drab	10	0
	Fire clay, hard, drab, and interval	10	0	1164	Coal, Harlan	5	8
	Sandstone, massive, cross-bedded	40	0		Interval, hidden	5	0
	Interval, hidden	8	0		Sandstone, massive, cross-bedded	30	0
	Sandstone, shaly, thinly laminated	15	0		Interval, hidden	10	0
	Clay shale	10	0		Sandstone, brown, massive	5	0
	Sandstone, massive	7	0		Sandstone, thinly laminated	30	0
					Clay shale	5	0

The section farther up Clover Fork, about opposite the mouth of Jones Creek, will give details from about the bottom of the last section for a short distance below.

Section on Clover Fork opposite Jones Creek.

No. on map.	Stratum.	Thickness.		No. on map.	Stratum.	Thickness.	
		Ft.	*in.*			*Ft.*	*in.*
	Sandstone, massive	40	0		Clay shale, light drab	6	0
	Shale	80	0	1176	Coal	2	6
	Sandstone, massive	4	0		Clay, light drab	3	0
	Clay shale, drab	6	0		Sandstone, brown, massive	10+	0
	Coal	1	7		Interval to bottoms on Clover Fork	25	0
	Interval, hidden	4	0				

The section from the Cawood sandstone down is well exposed in the point of the nose just north of Harlan. At that point it is as follows:

Section north of Harlan.

	Ft.	In.
Sandstone, yellow massive, Cawood	50	0
Shale, soft brown, running into sandstone toward the top	150	0
Shale, drab	40	0
Shale, black with thin plates of coal		3
Coal		4
Clay, drab	4	0
Shale, blue, to Harlan road	3	0

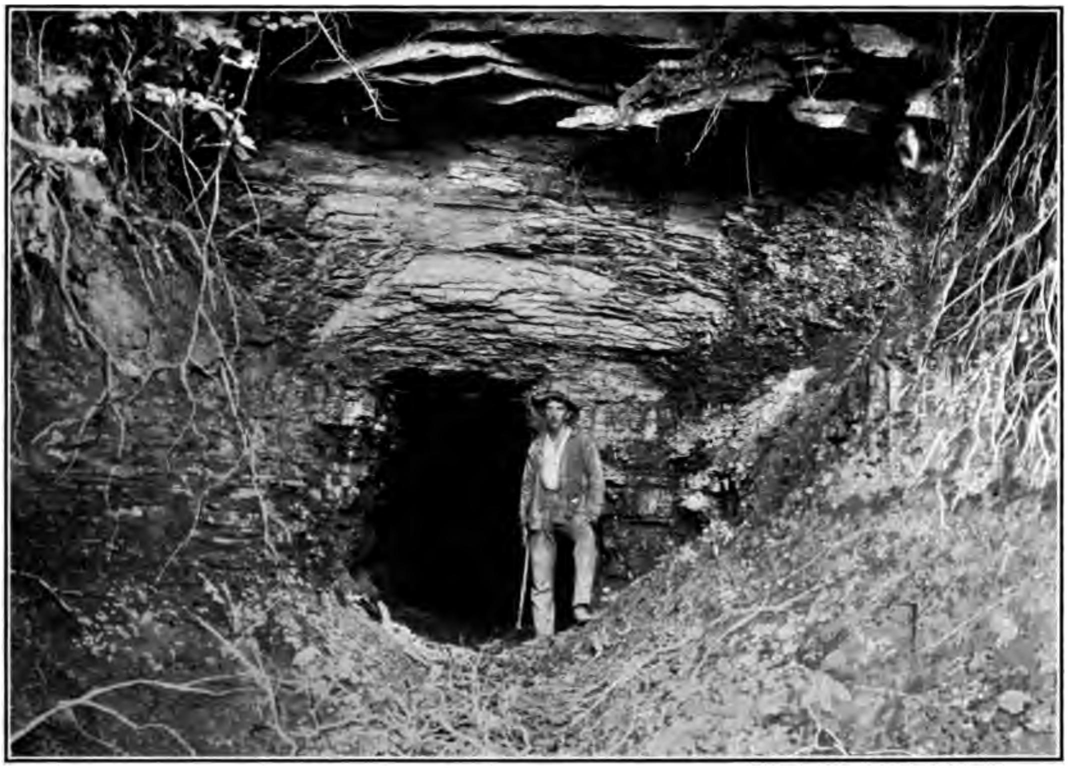
The top of the sandstone supposed to be the Yellow Creek sandstone shows about 30 feet lower down. The compiled section of Martins Fork, Turtle Creek, and other branches is as follows:

Skeleton section on Martins Fork and Turtle Creek (compiled).

	Ft.	In.
Sandstone, Reynolds	20–	0
Interval	130	0
Sandstone, Jesse	30	0
Interval	280	0
Coal, Wallins Creek	5	0
Interval	420	0
Coal, Creech (?)	2	9
Interval	200	0
Coal, Kellioka	2–3	0
Interval	230	0
Coal, Harlan	4–7	0
Interval	20	0
Coal	1	6
Interval	140	0
Coal	1	0
Interval	100	0
Coal	1–2	0
Sandstone, Cawood	90	0

COALS.

On account of the excellent character, good thickness, and low position in the mountains of the Harlan coal there has been little incentive in this and the Martins Fork and Upper Puckett districts to explore for the higher coals. All of the present possible needs can be met from the Harlan coal, which usually occurs low enough in the hill to enable it to be readily hauled out. As a consequence very few facings have been made on the higher coals, and unfortunately few places were found in this district where the higher coals were naturally exposed in the stream beds, so that our knowledge of these coals is very fragmentary and may or may not give an idea as to the actual coal content of the mountains. From the economic standpoint there are four coals, or possibly a fifth, which are or may prove workable—the Wallins Creek coal, well up in the mountain top; a coal which may be the representative of the Creech coal of Jackson Mountain, although it is much thinner here; the Kellioka



A. HARLAN COAL AT KELLY MINE, BAILEYS BRANCH OF CLOVER FORK.

B. HARLAN COAL IN MARTINS FORK DISTRICT.

coal, which locally is of good workable thickness; and the Harlan coal, which alone makes this region one of great promise. Below the Harlan coal were seen a few outcrops of coals, which in one or two places were of workable thickness. In this and in the Martins Fork and Upper Puckett districts the Harlan coal has been traced almost continuously by openings where sections can be measured, usually not over 3 or 4 miles apart.

COAL OF HANCE FORMATION.

In this district almost no coal of workable thickness was found below the Harlan coal. The best exposure was on Clover Fork, nearly opposite the mouth of Jones Creek (1176). The coal here showed a thickness of 30 inches, with a shale roof. A large number of points gave coals of from 1 foot to 18 inches. On the whole, the evidence did not bear out the idea that in the presence of the Harlan bed any of the coal below will be worked or may be considered as workable.

COALS OF MINGO FORMATION.

HARLAN COAL.

For a type locality of this coal bed we may take the Green Jones bank, or the Baker and Cornett, or the G. A. S. Kelly banks, all of which are just across Clover Fork from Harlan and all of which are upon the same seam. At the Green Jones bank (1162) there are several old openings from which the coal has been worked for some time. The coal shows an upper bench of from 3 feet 10 inches to 4 feet 4 inches. This bench alone is worked. Seven inches lower, the parting being shale, is a lower bench which runs from 12 to 14 inches thick. Over the coal is 1 inch of shale, then 1 inch of bony coal with shale roof above; 5 or 6 inches of the roof is draw slate, which does not always come down; 5 feet above the coal are 12 feet or more of massive sandstone. The lower bench would be taken out in entries. On the Baker and Cornett place (1164), which is but a short distance from the former, the coal shows almost exactly the same conditions of thickness and parting. The parting here is soft clay; the roof (shale) is 10 feet thick and good. A few inches tend to come down in spots. It is said that only an occasional plate of pyrite is met with in the mine. The floor is hard. At the G. A. S. Kelly opening (1165) the top bench is 4 feet 3 inches thick, the clay parting has thickened up to 13 inches, and there is 14 inches of bottom coal. The top 3 inches of coal is dry and splinty: above the coal are 6 inches of black shale, and from 1 to 2 inches of coal, 6 inches of black shale, and 4 feet of clay shale to the bottom of a massive sandstone. The lower bench here is not mined. The coal is reported very hard, being shot on the solid as a rule, it is sometimes undercut for a foot or two. Butts run S. 40° W. The roof is a soft, spongy shale, which tends to fall on weathering. It has generally been believed in this region that about 100 feet lower is another coal 4 feet thick. This belief seems to be based on the fact that on the north side of Clover Fork the Harlan coal has no bottom bench, or else the bottom bench is so far separated from the main bench as not to be distinguished, while the general dip into Big Black Mountain has carried the coal 100 feet lower.

The uppermost opening at which this coal was seen was near Kellioka post-office (1218), in the same ravine in which the best section of the Kellioka coal was found. The coal shows a total thickness of 61 inches, with a 7-inch parting 2 feet from the top, and a 3-inch parting 1 inch from the bottom. The roof is shale that is 6 feet or more in thickness. In Canoe Hollow of Poor Fork (1208) the seam has a total thickness of 6 feet 3½ inches and occurs in two benches, 30 and 39 inches thick, separated by 6½ inches of clay. This is on the John Sargent place. On the Nolan place (1207*a*), a little above the mouth of English Creek on Poor Fork, the coal shows a bottom bench of 4+ feet, with 1¼ inches of coal one-fourth inch above, and a thin streak of coal 2¼ inches above that. For a roof there are 8 feet of shale under a sandstone. On Little Lick Branch of English Creek this coal shows a main bench of 4 feet 4 inches, with 1+ feet of coal 2 feet 6 inches below (1222). The roof is a sandy shale 8 feet thick and is overlain by sandstone. Some distance lower down Poor Fork (1202) a poorly faced opening showed 4 feet of solid coal. It was reported at this place that 90

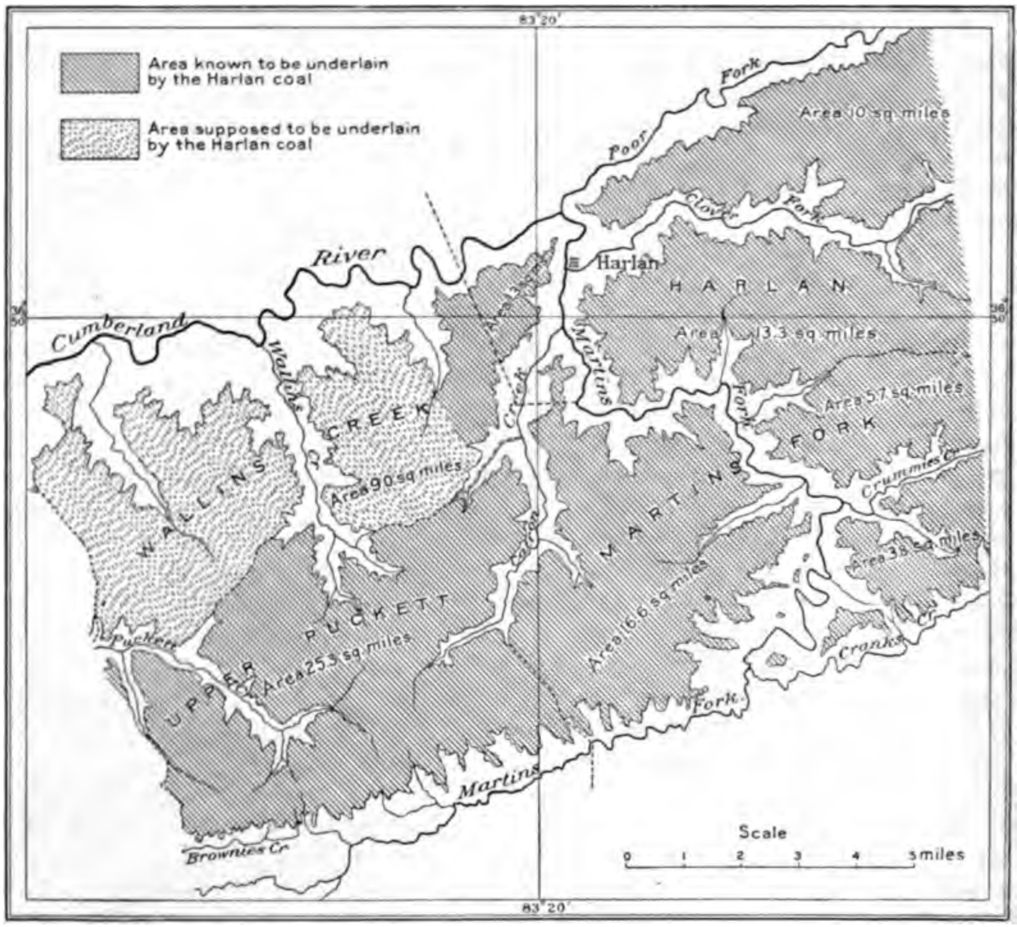


FIG. 13.—Map of Harlan coal in Harlan, Martins Fork, and Upper Puckett districts.

inches from the bottom and a 1-inch parting 10 inches higher up. The roof is a drab clay shale for at least 6 feet. On the Wright Kelly place on Bailey Branch of Clover Fork (north side of Clover Fork just east of edge of area mapped) (1171) the coal has been mined and several sections give a variety of measurements. There is a main parting of 7 to 12 inches at 19 to 21 inches from the bottom. This lower bench in some places shows an inch of clay 2 inches from the top. The top bench of coal carries two partings and is divided into three more or less nearly equal parts. The upper bench in different measurements varied from 11½ inches to 17 inches, the middle bench from 15 inches to 17 inches, and the lower part from 9 inches to 14 inches. The partings between these three benches are all quite thin, ranging from one-eighth to one-fourth inch. There is 6 feet of light-drab shale between the coal and the overlying massive to laminated sandstone. The floor is of clay. On the south side of Clover Fork no exposure of this coal was seen on Yocum Creek, which empties into Clover Fork just east of the area mapped. On Jones Creek one opening (1195) on this coal showed a total of 53 inches of coal, including one-half inch of shale at the top, the coal being in two main benches separated by 7 inches of fire clay. The upper bench is 25½ inches thick, including 1 inch of bone 6½ inches from the top. The lower bench is 20½ inches thick, including 3 inches of splinty coal at the top. Below is 1½ inches of shaly carbonaceous clay parting, then 3 inches of splinty coal, a knife-edge parting of shale, with 13 inches of coal below. The roof, as far as seen, is a sandy gray shale with hard sandstone just above. The floor is fire clay, with hard sandstone immediately below. On another point in this creek (1193) 26 inches of coal were seen which seemed to occupy the stratigraphic position of the Harlan coal, being overlain and underlain by a comparatively thick sandstone. On the Gabe Turner branch of Clover Fork this coal has been opened on the M. B. Smith place (1166). There are here about 40 inches of coal, with 1 inch of bone 4 inches from the top. Over the coal are from 15 to 17 inches of clay and shale, the latter of which is carbonaceous. From 3 to 4 inches of clay overlie that, with a shale roof above. The floor is fire clay. The faces run in a general way northeast and southwest. On Kitts Branch Messrs. McCreath and d'Invilliers report this coal (1238) as 4 feet 4 inches thick, with 1 inch of bone coal 5 inches from the top, with a shale roof.

The coal at the Kelly, Baker and Cornett, and Green Jones openings has already been described. Passing up Martins Fork it is exposed at the Skidmore opening (1160). The coal here measures from 3 feet 4 inches to 3 feet 8 inches, and is overlain by 20 feet of laminated to massive sandstone. Below is 1 foot of shale. It is reported that there are 18 inches of coal below that. On Farmers Branch of Martins Fork this coal has been mined on the W. C. Farmer place (1142). The coal here measures 4 feet 10½ inches, with 1 foot 6 inches of coal reported 1 foot below the main bench; below the coal are 2½ feet of clay shale with 20+ feet of shaly laminated sandstone above. The coal here has an actual elevation of 1,586 feet above tide. On Osburn Branch the coal has been opened upon the D. S. Farmer place (1139). As well as could be measured here, it is 4 feet 5 inches thick. There is 9 inches of shale here between the coal and the sandstone above. On Turtle Creek (1133) this coal has been opened on the Stephen

A. James Huff place above Harlan (1188).
B. William Smith place on Clover Fork (1180).
C. Wright Kelly place on Bailey Branch; sample is of the upper bench (1171).
D. Wright Kelly place on Bailey Branch, lower bench of coal (1171).
E. G. A. S. Kelly place opposite Harlan (1165).
F. W. C. Farmer place on Farmers Branch (1142).
G. Stephen Osburn place, Turtle Creek (1133).
H. Pennington place nearly opposite the mouth of Kitts Branch and Clover Fork.
I. Ball place on the right-hand branch of Ages Creek (1197).
J. J. B. Howard place on Kitts Branch (1238).
K. Green Jones bank just south of Harlan (1162).
L. J. C. Howard bank, 1 mile above Mount Pleasant, probably on Kitts Branch (1238).
M. Skidmore Creek of Martins Fork, possibly the same as (1160).

In comparing these analyses with those obtained in districts where active mining is going on, it must be remembered that the majority of these samples were obtained close to the outcrop, and the coal in most places is in a more or less weathered condition. In some cases, as shown by the high percentage of moisture, the coal was very much weathered, and no judgment could be made of its coking qualities. As far as the laboratory tests of the coke go, most of the recent samples appear to show this coal to produce a fair coke with a tendency toward a granular structure. It yet remains to have actual test made of the coal from one of the mines that have been driven back beyond the zone of weathering. Only such a test will give a fair idea as to the coke-producing qualities of this bed.

KELLIOKA COAL.

This coal is named from Kellioka, on Poor Fork. In Long Hollow (1212) it shows a bottom bench of 43 inches with four thin unworkable benches above: 5 inches above the main bench is a 4½-inch bench of coal, then over 7 inches of shale come 6½ inches of coal; 22 inches above that is another 6-inch bench of coal, while the top 2-inch bench of coal is 8 inches higher. Above the coal is 5 feet of sandy shale with sandstone over that. Only the lower bench of coal can be worked here. At the other opening in this neighborhood (1220) the lower bench is 4 feet thick—a good bright coal. Above that is 1½ inches of bone overlain by 3 inches of coal and another inch of bone with 5 inches of coal above that. Seventeen inches farther up is a 3-inch bench. The roof consists of 4 inches of sandy chip shale overlain by thin-bedded shaly sandstone. In this case the workable coal might be limited to a 48-inch bench unless the streaks of bony coal above prove to be of good enough quality not to injure the value of the coal. On Frank Branch of Yocum Creek, on the J. N. Little place (1169), just east of the eastern edge of the area mapped, this seam shows 47 inches of solid coal. It is there 225 feet above the Harlan coal. On Jones Creek of Clover Fork, on the William Turner place (1192), this coal shows a thickness of 45 inches without partings. On another branch of Jones Creek (1194) 24 inches of coal were seen at this horizon, the lower 6 or 8 inches being splinty. Reports and the length of the posts seen indicated that the coal here, all told, was 5 or 6 feet thick. In the section given—Bakers Branch, on Clover Fork above the Baker and Cornett opening—the 32-inch coal occupies about the position of this horizon (1235). On Turtle Creek 270 feet above the Harlan coal a thin coal was found on Frank Hawl's place under a sandstone which causes a waterfall in the bed of the creek (1128). The main bench of coal here is 26 inches thick; 20 inches above are 6 inches of coal, with a 1-inch parting of black shale 1 inch from the bottom. Over the coal are 1½ inches of black shale and 20 feet of sandstone. Until more exploitation has been done on this seam it is difficult to say how regular it will prove or how large an area of workable coal it will yield. The evidence, however, is sufficient to indicate that some workable coal, possibly a large amount, exists at that horizon. The following analysis of this coal was made in 1886 from a sample obtained by Messrs. McCreath and d'Invilliers:

Analysis of Kellioka coal from Frank Branch of Yocum Creek.

	Per cent.
Moisture	1.598
Volatile combustible matter	38.457
Fixed carbon	57.339
Sulphur	.671
Ash (color, brown)	1.394

This analysis shows an unusually fine coal at that point, though, as in similar cases, it is hardly safe to judge of the average quality of the coal from a single analysis. The ash here is exceptionally low, and the percentage of sulphur is below the average. The fixed carbon is a little above the others. It is said that a preliminary coking test of this coal was made in a small brick oven at the mouth of Frank Branch, and some remnants were seen by Messrs. McCreath and d'Invilliers and reported by them as of excellent character but imperfectly burned. Three feet from the bottom of the coal analyzed occurred 4 inches of dark-gray splinty coal in thin layers, such as in many of our samples is described as bony coal. The analysis indicates that in this case at least this splinty coal is equal to the rest of the coal in quality, and probably the same is true in a great many other cases.

CREECH (?) COAL.

As indicated in the skeleton sections already given, from 300 to over 400 feet above the Harlan coal occurs a coal that is slightly thicker than the minimum workable thickness. This varying interval leaves it questionable whether the various coals so correlated really belonged to the same bed or not. As the change in interval corresponds to the somewhat similar change in interval from Little Black Mountain toward Poor Fork, it is assumed that there is probably at about this horizon at least one coal that may be considered to be over 2 feet thick and ranging in places up to 3 feet thick. On Poor Fork this coal showed a thickness of 2 feet 2 inches on Little Lick Branch of English Creek (1225). As it is immediately overlain and underlain by sandstone, it can hardly be accounted a workable coal at that point. It there lies 350 feet above the town coal. The coal at about this horizon, as found on Jones Creek of Clover Fork, on the William Turner place (1191), shows an upper bench of 36 inches of splint coal, then 1 inch of bony shale, and 2 inches of clay to 3 inches of coal at the bottom. The floor is fire clay, and above the coal there are 4 inches of shaly clay below 5 feet of blue sandy shale, with massive sandstone above. On Frank Branch of Yocum Creek, at an elevation of 430 feet above the Harlan coal, is a facing of a coal on the C. Slemp place (1170). This showed 2 feet of coal, 7 inches of dark-drab clay, 1½ inches of coal, 2 inches of dark-drab clay, and 4 inches of coal at the bottom.

The roof is drab fire clay. Above the coal come 3 inches of black cannelly shale, then 10 feet of sandy shale, with 10 feet of shaly sandstone above. On Farmers Branch of Martins Fork, at an elevation of 425 feet above the Harlan coal, is a coal measuring 33 inches, without partings. It immediately underlies sandstone, and its actual elevation is 2,011 feet above tide (1145*a*). An analysis of a sample of this coal, obtained at this opening on Farmers Branch of Martins Fork, is as follows:

Analysis of Creech (?) coal on Farmers Branch of Martins Fork.

	Per cent.
Moisture	1.520
Volatile combustible matter	40.240
Fixed carbon	51.383
Sulphur	1.757
Ash	5.100

COALS OF CATRON FORMATION.

WALLINS CREEK COAL.

No outcrops of this coal were seen in Big Black Mountain, though its horizon was thought to have been found on the north side of the mountain at a level where coal blooms occurred at frequent intervals. These were traced some distance in the hope of finding a natural exposure, but without success; the line was marked by a line of springs. On the north side of Little Black Mountain Messrs. McCreath and d'Invilliers reported this coal as having been exposed in Kitts Branch of Clover Fork at an elevation of 1,200 feet above Clover Fork. There the section (1237) shows 7½ feet of coal, including a 6-inch clay parting 3 feet 8 inches from the top and a 1-inch shale parting 8 inches lower, with 3½ inches of coal and bone immediately below that, and a 1-foot shale appearing 1 foot 2 inches from the bottom. The roof here is shale. The only other exposures on this coal were two openings on the Taylor Low place near the head of Turtle Creek. At one of these openings (1126) the coal showed a total of 51 inches, including a ¾-inch parting 15½ inches from the top, a ½-inch shale parting 8 inches lower, a 1-inch clay parting 3 inches below with a clay parting 1½ inches thick 4 inches lower, a 2-inch clay parting 7 inches lower, and still lower a ½-inch shale parting 4 inches from the bottom. The roof was not exposed; the floor is fire clay. The butts of the coal run S. 20° E. The other opening (1129) shows a total thickness of 56½ inches; it shows 1 inch of clay 2 inches from the top, one-half inch of clay 26 inches lower, one-half inch of bony coal immediately below that, and 11 inches lower comes a 1½-inch clay parting, with 1 inch of bony coal 3 inches from the bottom. This coal has an actual elevation of 2,443 feet. According to these sections this coal does not compare in workability with the Wallins Creek coal in the district last described, though a better knowledge of it may show a large amount of workable coal. The quality of this coal is indicated by two analyses—an analysis of the Kitts Branch coal sampled by McCreath and d'Invilliers and an analysis of the coal at 1126 sampled in 1903.

Analyses of Wallins Creek coal.

	1237 (Kitts Branch).	1126 (Turtle Creek).
	Per cent.	*Per cent.*
Moisture	7.102	2.910
Volatile combustible matter	34.028	33.610
Fixed carbon	49.144	45.195
Sulphur	.846	.765
Ash	8.880	17.520

The sample of 1126 was taken between the top of the 15½-inch bench and the bottom of the 7-inch bench, so that it includes the ¾-inch clay parting, ½-inch shale parting, 1-inch clay parting, and 1½-inch clay parting. This fact doubtless accounts for the high percentage of ash; otherwise this analysis indicates a good quality of coal. The high percentage of water in the Kitts Branch analysis is probably due to the weathered condition of the coal at the time the analysis was obtained, and the high ash in that analysis Mr. McCreath thinks may be in part due to the fact that the coal there was somewhat mixed with mud seams at the outcrop. On the whole, neither of these analyses is to be considered as representative of what this bed will yield on an unweathered face and where not so badly split up by partings.

SUMMARY.

Summary of coals of Harlan district.

Number of coal beds found		18
Total thickness of coals	feet	20+
Number of coal beds of workable thickness 2+ feet		6
Average thickness of principal workable coals	feet	4
Total thickness of workable coal beds	do	14
Greatest thickness of single coal bed measured	do	8½
Greatest thickness of coal in single bed measured	do	5¾
Approximate area underlain by workable coal	square miles	25
Available coal in district	tons	150,000,000

	Wallins Creek.	Kellioka.	Harlan.
Approximate elevation, feet above tide	2,500	1,850	1,600
Thickness:			
Greatest, feet	7	8⅔	....
Average, do	$5\frac{5}{12}$	4½	....
Least, do	4¼	2	....
Average thickness of workable coal, do	3½	3½	4
Number of measurements	3	7	27+
Area of seam, acres	4,000	5,000	16,000
Total coal per acre, tons	9,000	7,000	6,560
Available coal per acre, do	5,000	4,000	5,500
Coal available in district, do	20,000,000	20,000,000	88,000,000

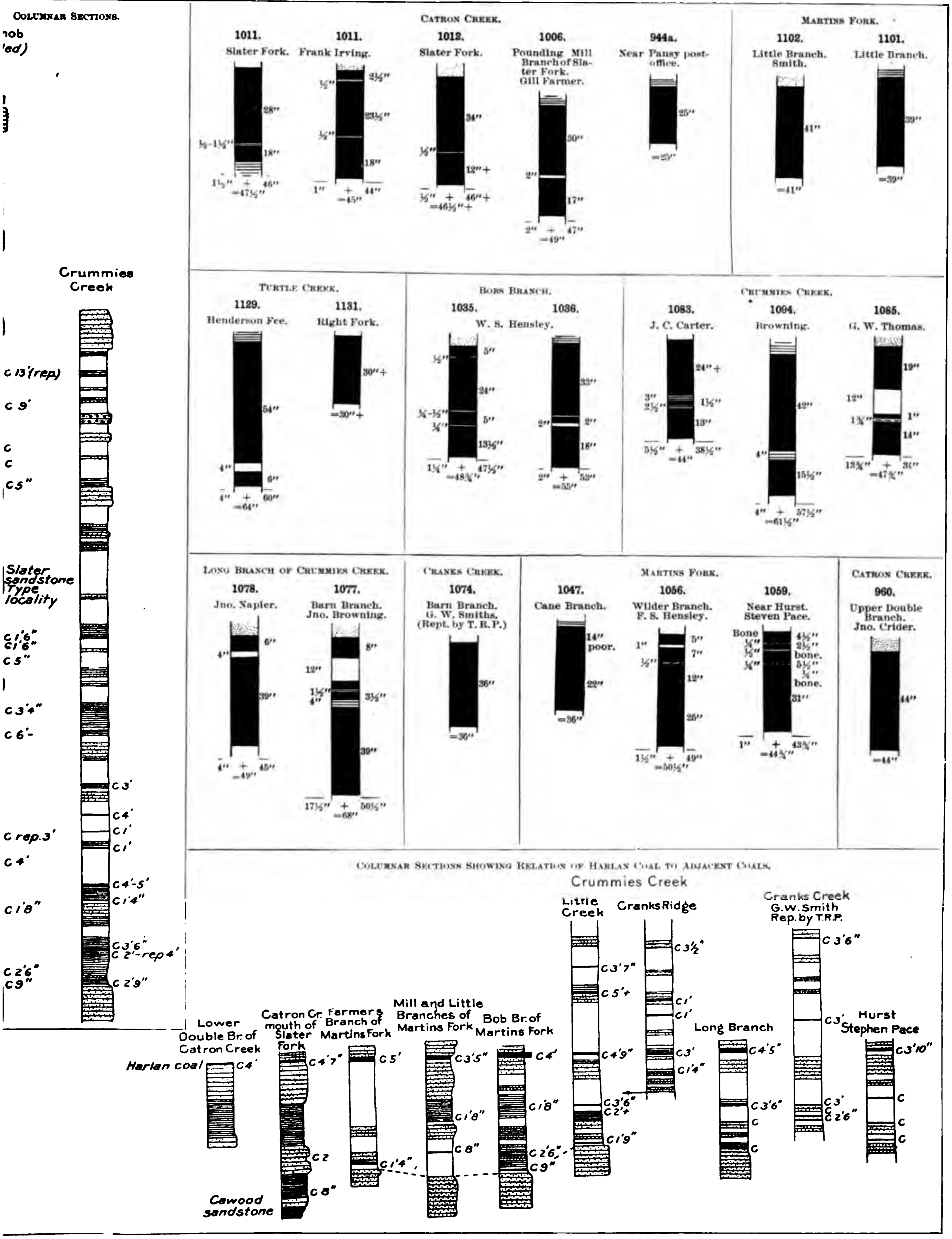
STRUCTURE.

The principal structural feature of this district is the syncline running through Big Black Mountain. At all points where the rocks on the Poor Fork side of this mountain were examined they dip to the south. This dip becomes more pronounced as the channel of Poor Fork is approached, so that at many points along the bank of Poor Fork it is from 30° to 40°. Southward toward the mountain this dip decreases rapidly and probably changes to a north dip under the crest of the mountain. On the Clover Fork side the rocks show a corresponding but opposite northward dip. This is very noticeable at the Turner opening already mentioned or in comparing the elevation of the Harlan coal on the north side of Clover Fork with its elevation on the south side. In the southern part of this district the exact structure is very obscure as the dips are very light. Elevations on the Harlan coal in the southern part of the district run within a few feet of 1,600 feet above tide. Up Clover Fork toward the east the rocks have a noticeable dip, bringing the Harlan coal at the eastern edge of the district more than 200 feet below its elevation at Harlan. On account of the high dips on the north side of Big Black Mountain the elevation of the Harlan coal varies with its distance horizontally from the crest of the mountain. It is safe to say that most of the streams cross its horizon on that side of the mountain at an elevation of about 1,600 feet. English Creek, because of cutting near the crest of the mountain, is crossed by the horizon of the Harlan coal at an elevation below 1,600 feet, and the elevation of this coal on the projecting headlands facing Poor Fork would be much higher. Near Harlan on the north side of Clover Fork this coal is a little below 1,600 feet in elevation, probably reaching 1,600 feet on the north side of Clover Fork between Kitts Branch and Ages Creek. At Ages Creek it is below 1,600 feet. Opposite Gabes Branch it has descended to 1,550 feet; on Jones Creek of Clover Fork to 1,500 feet; on Bailey Branch of Clover Fork just east of the border of the map to 1,460 feet; on Frank Branch of Yocum Creek just east of the map to 1,430 feet. From the Skidmore bank of Martins Fork to the Osburn bank on Turtle Creek the coal continues at an elevation of almost exactly 1,600 feet, there being a large area to the south of this where the coal lies nearly flat.

MARTINS FORK DISTRICT.

GEOGRAPHY.

This district lies in the southeast corner of the area examined, its boundary on the north running along Martins Fork to the mouth of Turtle, then up Turtle to the crest of the mountains and along that to the edge of the area mapped. On the west the boundary extends along Catron Creek, up Upper Double Branch, and straight over Martins Fork Ridge to Martins Fork. The valley of Martins Fork is the dominant feature, all of the drainage running into that stream. Martins Fork rises at the northwest corner of the district, and, after many windings, leaves the district at the southwest corner. Ridges and valleys are similar in character to those of the district last considered. Grays Knob (3,354 feet) is a conspicuous landmark in this district and Grays Knob Spur furnishes the largest body of coal. Crummies Creek flows in a narrow gorge near its mouth, but where it is above



COLUMNAR AND COAL SECTIONS, HARLAN COAL, MARTINS FORK DISTRICT.

Scales: Columnar sections, 1 inch=300 feet; coal sections, 1 inch=5 feet.

the horizon of the Cawood sandstone its valley is broad and flat. Above Cawood, Martins Fork for some distance cuts an unusually narrow channel, doubtless due to the fact that it is cutting through the Cawood sandstone. All of this region can be readily reached by railroad transportation either up Catron Creek or up Martins Fork and its branches, Turtle Creek, Crummies Creek, Bobs Creek, and others. At present there are no transportation facilities in this district, nor are any projected so far as known for the immediate future, notwithstanding the fact that our knowledge of the coals indicates this to be one of the most valuable parts of the field.

STRATIGRAPHY.

It is believed that the stratigraphy of this district has been worked out with some degree of satisfaction, due to the fact that the Cawood sandstone, which has its type locality at Cawood post-office, at the mouth of Crummies Creek, is above the main lines of drainage all through this district. It is accompanied by the Harlan coal, which lies about 250 feet above it and maintains a more or less uniform thickness of about 4 feet. About 250 feet above that again is the Kellioka coal of irregular, but often considerable thickness. These three horizons, which are traceable through most of the district, tie together the stratigraphy of the rocks near drainage. In the hilltops occurs the Wallins Creek coal with a thickness of 6 to 9 feet, and with sections that in one or two places are so nearly like the sections on Wallins Creek as to leave little doubt as to its correlation. Below the Wallins Creek coal in this district are two cliff-making sandstones, the upper of which is believed to represent the Puckett sandstone and the lower to be the Slater sandstone. The Puckett sandstone lies at approximately the same interval below the Wallins Creek coal as in Reynolds Mountain, while the Cawood sandstone is nearly double that distance below the Wallins Creek coal. On Grays Knob Spur the Slater sandstone is much the more prominent. It makes a rather prominent waterfall on Mill Branch of Martins Fork and around the headwaters of Pounding Mill Branch of Slater Fork, where it presents a thickness of 100 feet in places. Its type locality is on the west side of Grays Knob Spur, and the name Slater has been given to it from its occurrence around Slater Fork of Catron Creek. The Reynolds sandstone and Jesse sandstone are both recognized in this district. The Reynolds sandstone is quite prominent in the Little Black Mountain, where, on the ridge between Little Creek of Crummies and Jones Creek of Clover, it forms prominent cliffs, and is known as the Pilot Rock.

On Grays Knob its cliffs are not specially dominant over some of the other sandstones. The Jesse sandstone does not, as a rule, develop the characteristic coarse-grained conglomeratic facies. Near the headwaters of Turtle Creek the surface was strewn with pebbles of this character at about the horizon of the sandstone, but no outcrop of the sandstone itself was recognized. It is seen in place carrying pebbles on the Crummies Creek side of the ridge. At the head of Catron Creek again just off from the edge of this district it is quite characteristically developed. The Puckett sandstone, while a cliff-making sandstone in this district, does not usually appear to be more than 25 to 40 feet thick. The Cawood sandstone and the Harlan coal are the key rocks for this district.

The two sections given on Pl. XXVII, page 172, are from Grays Knob and Crummies Creek. The one on Grays Knob is compiled from two climbs of the Knob from Bobs Creek, including the coals found on lower Bobs Creek, certain coals found in Pounding Mill Branch of Slater Fork of Catron Creek, and coals and sandstones on Mill Creek. Difference in total length of the two sections would suggest errors either in the correlation of the rocks or in the barometric readings of intervals. However, the two sections have been carefully adjusted to the total elevations of the mountain tops at the two upper limits, and the level of the basal sandstone at Martins Fork. The sandstones at the base of the section are the same, both occurring at Cawood, one at the mouth of Bobs Creek and the other at the mouth of Crummies Creek. The Grays Knob section is as follows:

Condensed section on Grays Knob.

	Ft.	In.
Interval, mostly sandstone	400	0
Sandstone, Reynolds	50	0
Interval	110	0
Sandstone, Jesse	70	0
Interval	80	0
Coal, Smith 11-foot, reported	13	0
Interval	90	0
Coal, Wallins Creek	9	0
Interval	80	0
Coal, bloom	......	
Interval	40	0
Coal, bloom	......	
Interval	45	0
Coal		5
Interval	10	0
Sandstone, Puckett	30	0
Interval	140	0
Sandstone, Slater	100–60	0
Interval	100	0
Coal	1	6
Interval	20	0
Coal	1	6
Interval	30	0
Coal		5
Interval	110	0
Coal	3	4
Interval	60	0
Coal, Kellioka	[a]6	0
Interval	220	0
Coal, reported	3	0
Interval	60	0
Coal, Harlan	4	0
Interval	110	0
Coal	1	8
Interval	140	0
Coal	2	9

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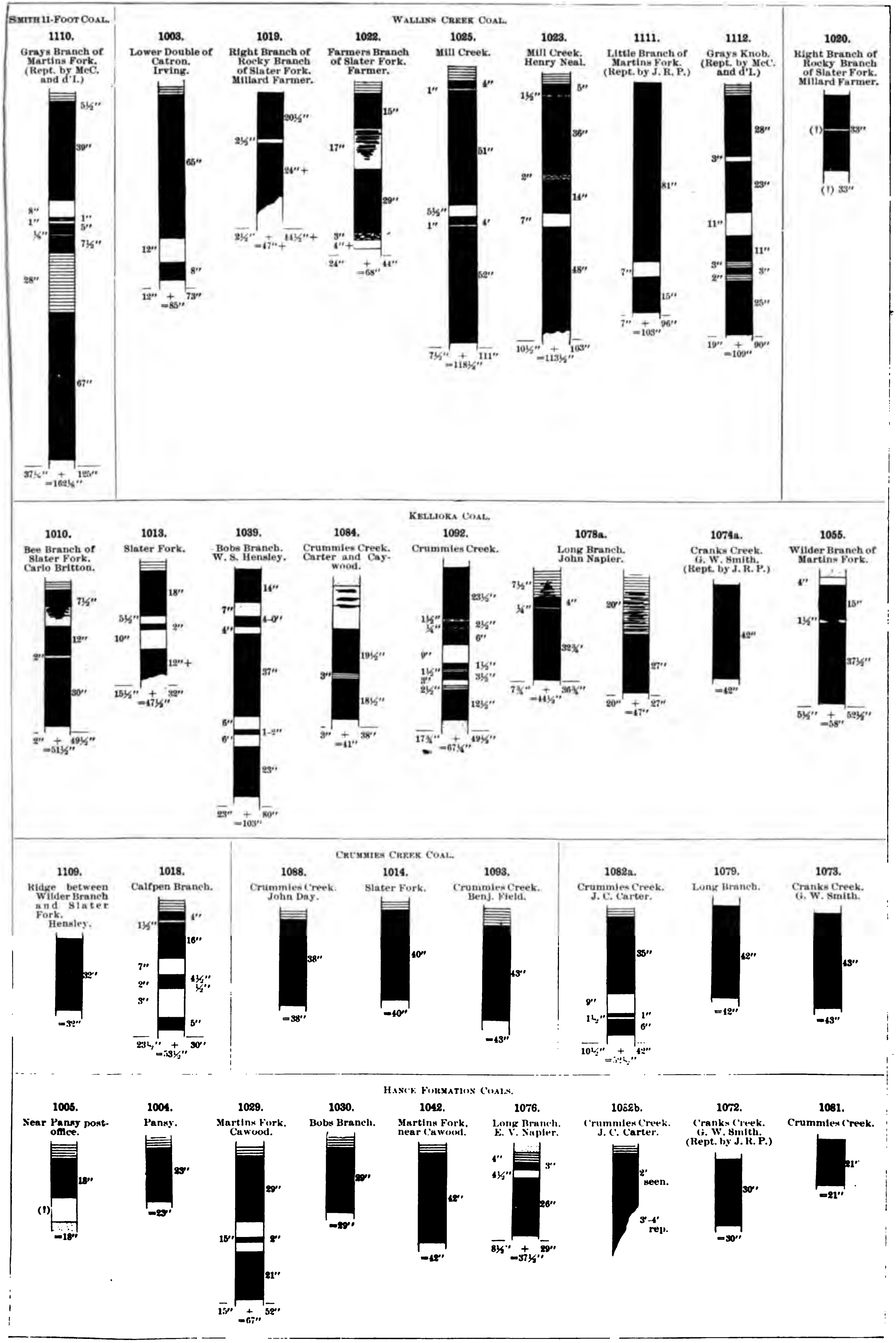
[a] Up to 6 feet.



COAL SECTIONS, MARTINS FORK DISTRICT.

Scale: 1 inch=5 feet.

	Ft.	In.
Interval	25	0
Coal		9
Sandstone, Cawood	80	0

Condensed section on Crummies Creek.

Sandstone, Reynolds, "Pilot Rock"	80	0
Interval	140	0
Sandstone, finely conglomeratic, Jesse	20	0
Interval	800	0
Coal	3	0
Interval	70	0
Coal, Kellioka	4	0
Interval	40	0
Coal	1	0
Interval	30	0
Coal	1	0
Interval	80	0
Coal, Harlan	4	0
Interval	25	0
Coal	1	4
Interval	110	0
Coal	3	6
Interval	15	0
Coal	2+	0
Interval	70	0
Coal	1	9
Sandstone, Cawood	70	0

COALS.

The principal coals of this district are the Smith 11-foot coal reported on Grays Knob, the Wallins Creek coal, which was measured at a number of points, a coal above the Kellioka coal, the Kellioka coal, a coal a short distance above the Harlan coal, the Harlan coal, and from one to three coals below the Harlan coal whose stratigraphic correlations are not entirely clear.

COALS OF HANCE FORMATION.

In this district practically all the coals exposed in the Hance formation come above the Cawood sandstone. At several points these coals have a thickness of 3 feet and over, but as a rule it was not possible to correlate any of these over any broad horizon, so we can not assert the workability of any of these over any large area in the district. It will be convenient to consider them by localities.

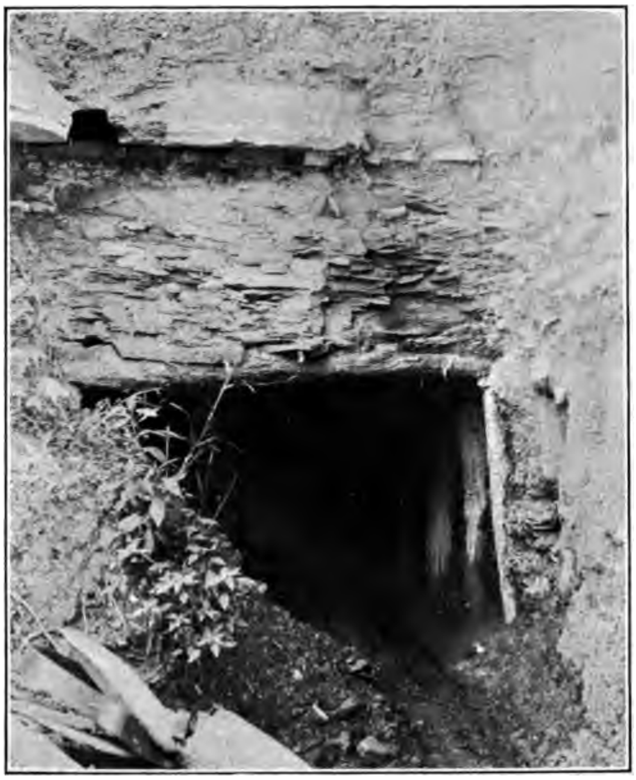
On Catron Creek a coal, which ranges from 18 inches to 2 feet, is practically 200 feet below the Harlan coal and between two massive sandstones. This coal can be traced up Slater Fork from above its mouth nearly to the mouth of Pounding Mill Branch. Below the mouth of Slater Fork it was thought that this coal was seen at two or three points. Its greatest thickness showed on the west side of Catron Creek, on Enoch Branch, and will be considered under the description of the next district. On Mr. G. W. Aeger's land, on Fee Branch of Catron Creek, a 28-inch coal was found, with a knife-edge of clay 8 inches from the bottom, at a barometric elevation of 1,435 feet. Over it is 6 inches of shale and sandstone (1021*a*). An analysis of this coal is as follows:

Analysis of coal on George W. Aeger's place.

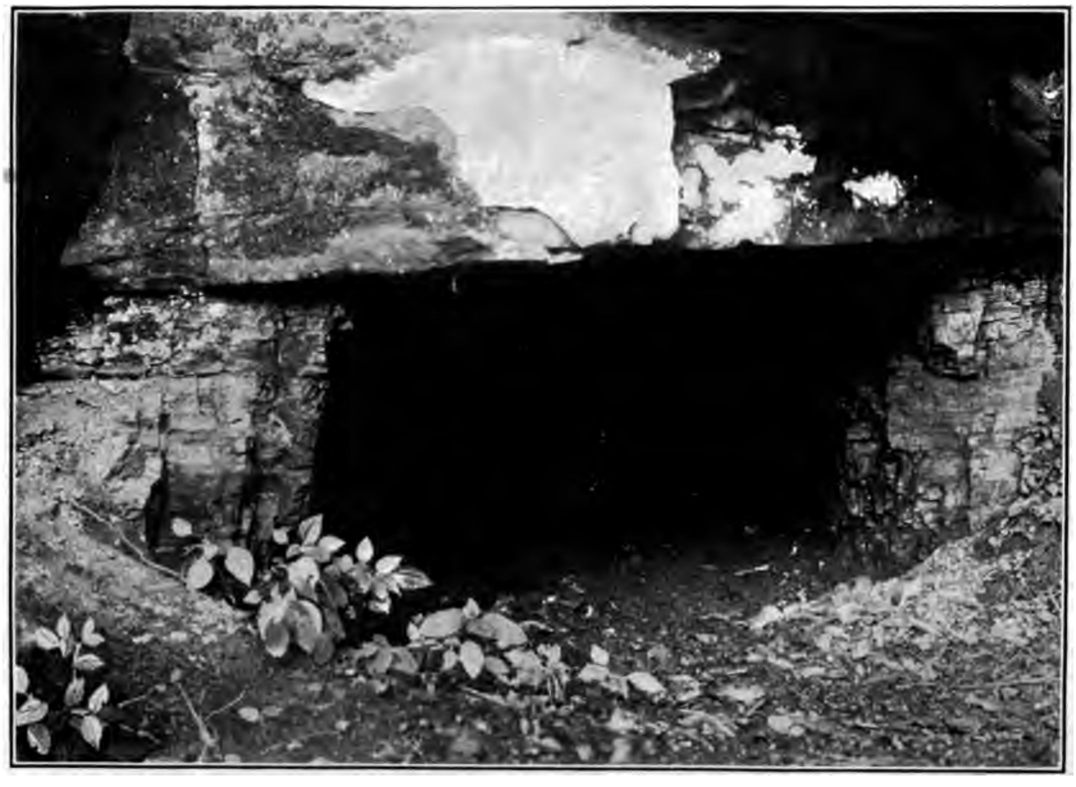
	Per cent.
Moisture	1.794
Volatile hydrocarbons	36.786
Fixed carbon	57.639
Ash	2.920
Sulphur	.861

Other coals less than 1 foot in thickness were seen below the horizon of this coal. Two coals were seen on Grays Branch; the lower one, 8 inches thick and at an elevation of 1,320 feet, appeared to be 50 feet above the top of the Cawood sandstone; the other coal, 20 inches thick, was 60 feet higher. On the north side of Martins Fork opposite this, coals at probably the same horizons show, the upper of which at one point was reported to be 30 inches thick.

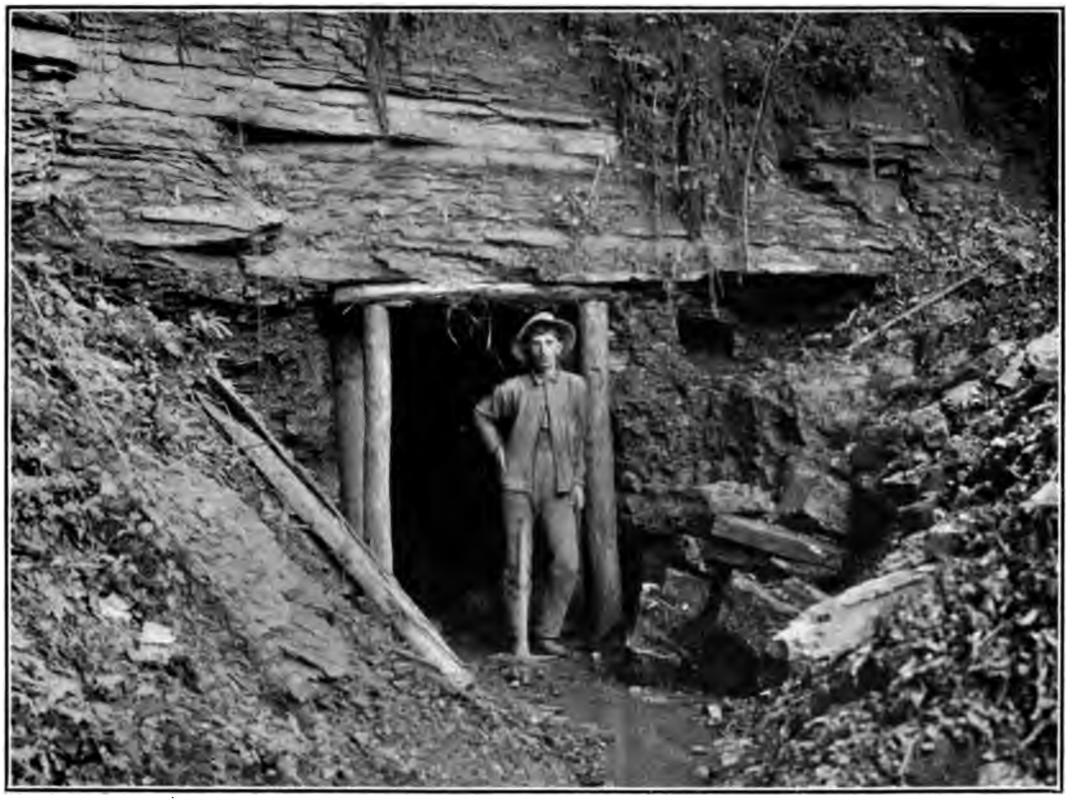
A short distance below the mouth of Bobs Creek, on the Steven Cawood place, on the west side of Martins Fork (1029), a coal has been opened at apparently the horizon of the lower of the last two mentioned coals. At this point, however, it shows two benches, of which the upper is 2 feet 5 inches thick and the lower 21 inches thick, separated by 15 inches of clay streaked with coal. The roof here is a dark-drab sandy shale. Below the coal is a drab fire clay. (See Pl. XXX, *A*.) Up Bobs Creek this same coal, judging from its stratigraphic position, showed a thickness of 2 feet 5 inches (1030). The roof here was dark-blue shale. Farther up Bobs Creek (1033) it has been stripped and was reported as 30 inches thick. Thirty feet below this and immediately on top of the Cawood sandstone is an 8-inch coal, while a 20-inch coal was noted about halfway vertically between this and the Harlan coal (1037). On the north or northeast side of Martins Fork, nearly opposite the mouth of Bobs Creek (1130*a*), the coal lying immediately on top of the Cawood sandstone appears to have been formerly mined a little, though the opening has now fallen in. Farther up between the mouth of Bobs Creek and the mouth of Crummies Creek two coals 20 feet apart are seen outcropping at a number of points (1095–1098), though at none of these points was it possible to measure a section of either coal. The lower of these lies immediately on top of the Cawood sandstone. Up Crummies Creek the coal immediately above the Cawood sandstone shows just where that sandstone runs under the creek (1081). This is on the William Browning place and the coal has been mined a little. It shows a thickness of only 21 inches and is overlain by 4½ feet of dark-blue shale and underlain by 12 inches of fire clay with 3 inches of carbonaceous shale below. About 60 feet stratigraphically higher and farther up Crummies Creek (1082) two coals 9 feet apart have been opened. The upper of these shows an upper bench of 35 inches, then 9 inches of fire clay, 1 inch of coal, 1½ inches of shale, and a bottom bench of coal 6 inches thick. Nine feet below, the interval being shale, about 2 feet thickness of coal was seen. This bottom bench is reported to be from 3 to 4 feet thick. This is on the J. C. Carter place. Over the coal is 30 feet of shale. These coals outcrop in the stream bed just above the mouth of Little Creek of Crummies (Pl. IV, *B*). On Long Branch of Crummies the coal immediately above the Cawood sandstone was seen (1081), but



A. COAL AT DANIEL BROWNING'S, CRUMMIES CREEK.

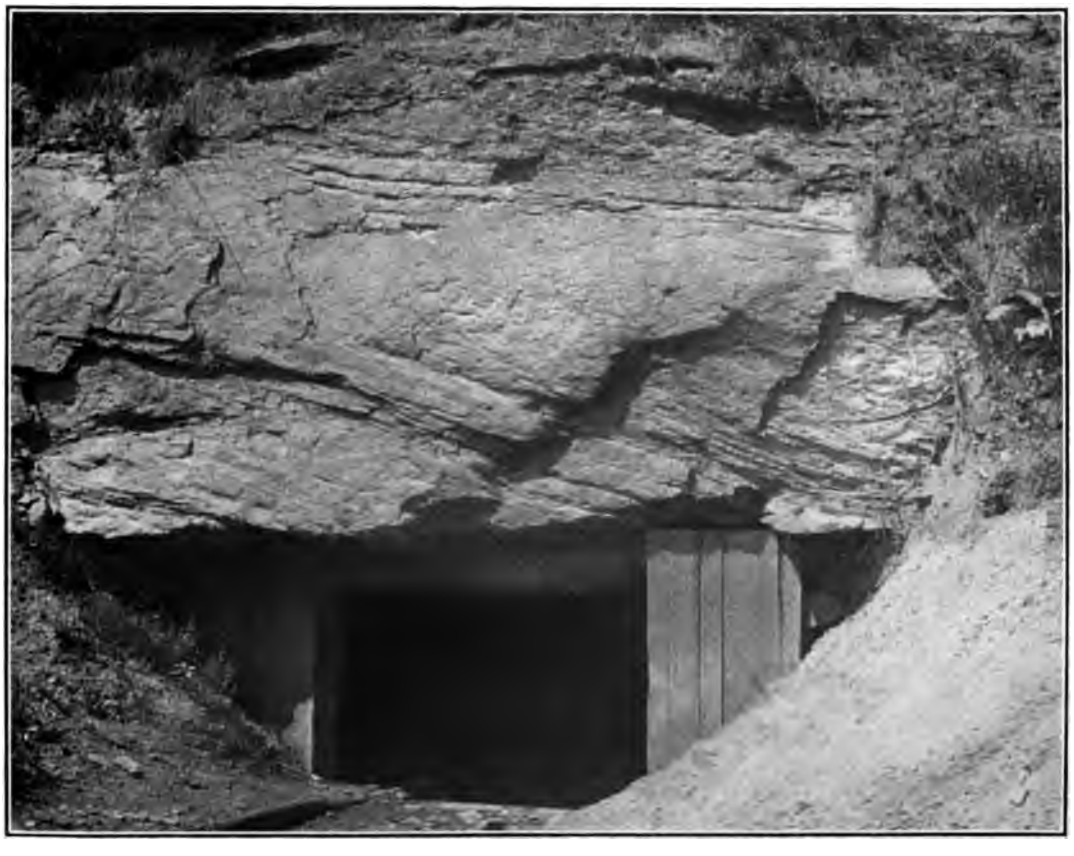


B. COAL AT G. NOE'S OPENING, MARTINS FORK DISTRICT.



A. COAL AT STEPHEN CAWOOD'S BANK, MARTINS FORK DISTRICT.

View showing opening 20 feet above Cawood sandstone, below the mouth of Bobs Branch.



B. HARLAN COAL ON STEPHEN FEE'S PLACE, TIMBER RIDGE BRANCH OF MARTINS FORK.

View showing character of roof.

as that includes 12 inches of fire clay below the top bench of 19 inches of coal and 1¾ inches of shale 1 inch lower, the coal can hardly be considered as workable at this point. Here the coal was about 30 feet barometrically lower than at the Carter and Cawood bank. Some question has been raised as to whether these are all the same coal, but the resemblance between the coal sections as well as their relationship to the sandstones above and below seem to indicate that they are. Several openings have also been made on Long Branch of Crummies Creek. On the southwest side of the creek, on the John Napier place, the coal has a total thickness of 4 feet and 1 inch, including a 4-inch parting of clay 6 inches from the top; the roof is sandstone. On the John Browning place, on the north side of the creek, the upper and lower benches of coal remain at about the same, but the parting has thickened to about 23 inches, including 12 inches of carbonaceous fire clay, 2 inches of coal, 1½ inches of carbonaceous shale, 3½ inches of coal, and 4 inches of carbonaceous shale. The roof here is also sandstone. Other openings on this branch had fallen shut when examined. Crossing over to Cranks Creek, openings were formerly made on several coals on the G. W. Smith place. Mr. John R. Proctor reports the one which is considered to be the horizon of the Harlan coal as showing 36 inches of coal without partings. On Martins Fork below Smith this coal was seen on Cane Branch (1047), where it gave a total thickness of 36 inches, the upper 14 inches being weathered and poor. The roof here was shaly. Farther up Martins Fork on the ridge on the right of Wilder Branch one-fourth mile from the mouth this coal has been opened up on the F. S. Hensley place (1056). It shows a total thickness of 50½ inches, including 1 inch of clay 5 inches from the top and one-half inch of bony coal 7 inches lower. The floor here is a blue clay. Just below Hurst post-office on Martins Fork (1059) this coal has been mined locally on the Stephen Pace farm about 200 feet above the valley. The coal shows a total thickness of 44¾ inches. It has streaks of bone coal 4½ inches from the top and 2½ inches lower, and bone one-half inch below that. The roof is shale, of which from 10 to 12 inches are taken down for head room; the floor is a soft clay. Considering these sections together, the coal in this district shows an average thickness of a little less than 4 feet, nearly all of which in most cases can be obtained in mining. It will be noted that in a large number of cases the roof is sandstone, or there is only a small thickness of shale between the coal and a somewhat massive and thick sandstone bed just above. In most cases also there is a thick, fairly massive sandstone close below the coal, which may in some cases reach a thickness of from 60 to 100 feet, though usually it is not over 50 to 60 feet. In most cases where there are partings these are only thick enough to serve to assist in mining, so that on the whole while the coal does not show quite as good sections as in the preceding district, it probably can be counted upon as workable over the larger part of the area underlain by it. The following analyses by A. S. McCreath from samples obtained in 1892-3 will give a fair idea of its quality in this district:

with the coal just described on Slater Fork. At this point the upper coal shows a thickness of 43 inches of bright, partly splinty coal with thin, irregular partings but no regular parting. Under it is a sandy fire clay, and over it 2 feet of shale and 1 foot of shaly sandstone with 8+ feet of shale above. On the John Day place on Crummies Creek (1088) was seen a 38-inch coal without partings. Over it were 3 feet of shale to 6+ feet of sandstone. The floor is fire clay. The coal is bright and good looking. The resemblance of this coal to the coal just described on the Benjamin Field place has made it seem possible that it is the same coal rather than the Kellioka coal whose horizon would come nearly to this level.

COALS OF CATRON FORMATION.

WALLINS CREEK COAL.

The Wallins Creek coal was seen at several openings, probably at enough to warrant our asserting that it will yield workable coal at this horizon all through the Martins Fork and Grays Knob ridges. The ridges south of Martins Fork above Cawood are probably not high enough to catch this coal and while indications are that it underlies the portion of Little Black Mountain in this district, it is not certain that it will prove workable there. The following section of this coal measured or reported will show its thickness in this district. On Mahlan or Lower Double Branch of Catron Creek it is opened on the Mahlan Irving place (1003) at an elevation a little above 2,500 feet, and shows a total thickness of 7 feet and 1 inch, including a 12-inch parting of creamy-white fire clay 8 inches from the bottom. The floor is a drab fire clay. The roof is composed of 1 foot of dark-drab clay shale which tends to come down in mining, being overlain by 15+ feet of light-drab and brown sandy shale. An entry has been driven in about 35 feet here on the faces, which run southeast and northwest. Supposedly the same coal has been opened on the Millard Farmer place, on the right-hand branch of Rocky Branch of Slater Fork of Catron Creek (1019), and at this point the coal has an actual elevation of 2,615 feet. As far as could be measured, it showed a thickness of 47 inches with a 2½-inch parting 20½ inches from the top. It is reported as being much thicker. The sandstone outcrops a short distance above the coal, but neither the roof nor floor was seen. On the G. F. Farmer place, at the head of Farmers Branch of Slater Fork (1022), this coal was opened at a barometric elevation of 2,640 feet, which shows a top bench of coal 15 inches thick; then a parting of 20 inches of bone coal and clay, of which the upper half is full of coal streaks one-fourth inch thick; then 29 inches of coal, including a 3-inch band 2 inches from the top, which is soft and is mined. Below that are 3 inches of very hard nearly black bone, which forms the floor of the mine. Below that is light-yellow fire clay 4 inches thick. The roof is shale 12 feet thick, with sandstone over it. It is reported that under the coal exposed in the opening are two benches, thought to be 15 inches thick, there being reported to be 6 feet of coal running in the whole seam. The faces run northeast and southwest. At this opening a number of specimens were obtained of *Sphenopteris tenella* Brongn., reported by Mr. David White as a type common in the lower Kanawha formation. Two measurements were obtained of a very thick coal in different branches of

Mill Creek. This coal was supposed to be the Wallins Creek coal. At one point the measurement gave a total thickness of 9 feet 10½ inches, including a 1-inch parting 4 inches from the top and 5½ inches of parting 51 inches lower down, and a 1-inch parting 4 inches below that (1025). At another exposure the coal showed a thickness of 9 feet 5½ inches. This showed 1½ inches of bone 5 inches from the top, 2 inches of bone 3 feet lower down, 7 inches of clay 14 inches below that, with 4 feet of coal in a lower bench, as far as it could be exposed. The roof here is a clay shale 15+ feet in thickness. At the first of these exposures the coal has an actual elevation of 2,482 feet and lies 340 feet above a sandstone which makes a waterfall in the creek bed where two principal forks of the creek come together. The upper coal in the first opening shows hard streaks in the upper bench, while the lower bench is softer, showing some brownish streaks with thin plates of bony coal. The two analyses obtained at the first of these openings are of the 51-inch bench and of the coal below the 5½-inch parting. In John R. Proctor's report on this region he gives a section of this coal on Little Branch of Martins Fork which almost exactly resembles the section obtained on Lower Double Branch. It shows a total of 8 feet 7 inches, including a 7-inch fire-clay parting 15 inches from the bottom. Messrs. McCreath and d'Invillier's section of the lower of the two coals discovered by them in Grays Branch on Grays Knob gave a total thickness of 9 feet 1 inch, including a 3-inch clay band 28 inches from the top, 11 inches of fire clay 23 inches lower, 3 inches of shale 11 inches below that, and 2 inches of shale 25 inches from the bottom. On Turtle Creek two exposures of coal supposed to be at this horizon were found near the head. One of these gave the following section: Coal, 15½ inches; clay, three-fourths inch; coal, 8 inches; shale, one-half inch; coal, 3 inches; clay, 1 inch; coal, 4 inches; clay, 1½ inches; coal, 7 inches; clay, 2 inches; coal, 3½ inches; shale, one-half inch; coal, 4 inches. The coal is overlain by soft clay and underlain by a fire clay. The sample obtained at this opening included from the top of the 15½-inch bed to the bottom of the 7-inch bench, so that it included all told 3¾ inches of parting, probably none of which could be separated in actual mining. The entry here runs S. 20° E. on the butts. The other opening showed coal, 2 inches; clay, 1 inch; coal, 26 inches; clay, one-half inch; bony coal, one-half inch; coal, 11 inches; clay, 1½ inches; coal, 13 inches; bony coal, 1 inch; coal, 3 inches. This opening has an elevation of 2,443 feet. Both openings are on the Taylor Low farm. Above the coal numerous fragments of coarse grit occurred which are supposed to have come down from the Jesse sandstone. These were followed up the hill, but no ledge in place was found. They appeared to come from about 300 feet above the coal, a fact which suggested the presence of the Jesse sandstone at that height above the coal, and at an interval which corresponds closely with the interval between the Wallins Creek coal and Jesse sandstone in the Wallins Creek district.

drab clay shale with a thickness of over 10 feet. The coal is here about 15 feet above the creek bed. On Little Branch of Martins Fork, just north of Grays Knob, the coal is seen in the bed of the branch and also in a mine on the Smith place. Its elevation is approximately 1,595 feet (1101, 1102). The coal at both places measures from 3 feet 3 inches to 3 feet 5 inches thick without partings. The roof is brown shaly sandstone. Below is 18+ inches of light-gray fire clay. In the creek bed there are above the coal 8 feet of shale with 30 feet of laminated sandstone above that. On Turtle Creek this coal has already been described at the Stephen Osburn opening. It makes even a better showing at the Henderson Fee opening in the nose of the hill between the right and middle forks (1129). The coal shows an upper bench of 4 feet 6 inches with a hard bony parting 2 feet 1 inch from the bottom, then below from 3 to 4 inches of clay is a 6-inch bottom bench of coal. Over the coal is 3 feet of light-drab shale with sandstone above. In mining it is found advisable to leave the top 3 inches of the coal as a roof. At some points a number of thin clay partings break the coal up rather badly. On the right-hand fork of Turtle Creek, at an elevation of 1,612 feet, the same coal is partly exposed in the bank beside the stream bed. Two feet 6 inches were seen overlain by sandstone. As at the Stephen Osburn place a 15-inch bench of coal occurs about 15 to 20 feet below the principal coal; at this point being found beneath a hard sandstone that produces a small rockhouse or fall in the bed of the stream. On Bobs Creek the Harlan coal was seen at two places, both on the W. S. Hensley farm. In Grapevine Hollow (1035) the coal shows a total thickness of 4 feet, with one-half inch of hard coal 5 inches from the top, with from one-fourth to one-half inch of clay 2 feet lower, and a ¼-inch streak of pyrite 13½ inches from the bottom. On the north side of the creek it shows a total thickness of 4 feet 7 inches, including a thin parting 33 inches from the top and a 2-inch parting 2 inches lower (1036). At the first place the roof is a laminated sandstone 10 feet or more in thickness; the floor is clay. At the second place the roof is of shale. On Crummies Creek a number of openings have been made upon this coal. The first of these, on the north side, is on the Daniel Browning place (1094). The coal shows a total section 5 feet 1½ inches thick, including 4 inches of shale 15½ inches from the bottom. The 42-inch upper bench is partly splinty. Over the coal is 8 feet plus of sandy shale. Twenty feet or more of sandstone outcrops immediately below. On Little Creek of Crummies (1091) the coal at one point has been mined and reported as from 5 to 6 feet thick. On the J. C. Carter place (1083), on the main creek, the coal shows a total thickness of 44 inches, but includes two partings. The upper is 3 inches thick, the lower 2½ inches thick 13 inches from the bottom. The top of the upper bench of coal was not seen here; the floor is fire clay. On the Carter and Cawood land (1084) is a coal which, though at an elevation of 90 feet higher than the last, has been thought to be the same coal. It shows 41 inches of coal with a 3-inch parting of carbonaceous shale 19½ inches from the top. Over the coal is 20 inches of fire clay with streaks of coal from 1 to 2 inches thick 8 inches from the top. Above the fire clay is 12 feet of sandstone. On the G. W. Thomas place (1085) the coal resembles the coal on the J. C. Carter place in having two partings with a 1-inch band of coal in the middle, and it resembles the coal at the last place in being overlain by fire clay with massive sandstone above. It shows a total thickness of practically 4 feet, but as that includes 12 inches of fire clay below the top bench of 19 inches of coal and 1¼ inches of shale 1 inch lower, the coal can hardly be considered as workable at this point. Here the coal was about 30 feet barometrically lower than at the Carter and Cawood bank. Some question has been raised as to whether these are all the same coal, but the resemblance between the coal sections as well as their relationship to the sandstones above and below seem to indicate that they are. Several openings have also been made on Long Branch of Crummies Creek. On the southwest side of the creek, on the John Napier place, the coal has a total thickness of 4 feet and 1 inch, including a 4-inch parting of clay 6 inches from the top; the roof is sandstone. On the John Browning place, on the north side of the creek, the upper and lower benches of coal remain at about the same, but the parting has thickened to about 23 inches, including 12 inches of carbonaceous fire clay, 2 inches of coal, 1½ inches of carbonaceous shale, 3½ inches of coal, and 4 inches of carbonaceous shale. The roof here is also sandstone. Other openings on this branch had fallen shut when examined. Crossing over to Cranks Creek, openings were formerly made on several coals on the G. W. Smith place. Mr. John R. Proctor reports the one which is considered to be the horizon of the Harlan coal as showing 36 inches of coal without partings. On Martins Fork below Smith this coal was seen on Cane Branch (1047), where it gave a total thickness of 36 inches, the upper 14 inches being weathered and poor. The roof here was shaly. Farther up Martins Fork on the ridge on the right of Wilder Branch one-fourth mile from the mouth this coal has been opened up on the F. S. Hensley place (1056). It shows a total thickness of 50½ inches, including 1 inch of clay 5 inches from the top and one-half inch of bony coal 7 inches lower. The floor here is a blue clay. Just below Hurst post-office on Martins Fork (1059) this coal has been mined locally on the Stephen Pace farm about 200 feet above the valley. The coal shows a total thickness of 44¾ inches. It has streaks of bone coal 4½ inches from the top and 2½ inches lower, and bone one-half inch below that. The roof is shale, of which from 10 to 12 inches are taken down for head room; the floor is a soft clay. Considering these sections together, the coal in this district shows an average thickness of a little less than 4 feet, nearly all of which in most cases can be obtained in mining. It will be noted that in a large number of cases the roof is sandstone, or there is only a small thickness of shale between the coal and a somewhat massive and thick sandstone bed just above. In most cases also there is a thick, fairly massive sandstone close below the coal, which may in some cases reach a thickness of from 60 to 100 feet, though usually it is not over 50 to 60 feet. In most cases where there are partings these are only thick enough to serve to assist in mining, so that on the whole while the coal does not show quite as good sections as in the preceding district, it probably can be counted upon as workable over the larger part of the area underlain by it. The following analyses by A. S. McCreath from samples obtained in 1892–3 will give a fair idea of its quality in this district:

Analyses of Harlan coal in Martins Fork district.

Constituent.	A.	B.	C.	D.	E.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	1.502	2.240	1.692	2.124	1.600
Volatile hydrocarbons	37.518	38.310	38.578	38.946	39.380
Fixed carbon	55.648	56.256	56.175	55.778	54.996
Ash	4.630	2.470	2.760	2.450	3.270
Sulphur	.702	.724	.795	.702	.754

A Frank Irving place on Slater Fork (1011).
B. W. S. Hensley place in Grapevine Hollow of Bobs Creek (1035).
C. John Napier place on Long Branch of Crummies Creek (1078).
D. F. S. Hensley place on Wilder Branch of Martins Fork (1056).
E. Stephen Pace mine on Martins Fork below Hurst (1059).

These analyses show a coal very low in moisture, about or below the average in sulphur, running about three-fourths of 1 per cent, and low in ash. The total amount of combustible matter is high, but of this the volatile hydrocarbons are above the average, so that the proportion of fixed carbon is only about an average. On the whole, these show this coal to be excellent, though probably not as much a coking as a gas coal or a coal for steam purposes. Considering its thickness and workability, this bed by itself gives value to the whole district.

Analysis of coal on Field place on Little Branch of Crummies Creek.

	Per cent.
Moisture	3.140
Volatile hydrocarbons	38.440
Fixed carbon	55.330
Ash	2.530
Sulphur	.560

KELLIOKA COAL.

As in some of the preceding districts, the Kellioka coal yields a large total thickness but is generally so split up with partings as to render its workability questionable in parts of the district. On Slater Fork it has been mined on the Carlo Britton place on Bee Branch. The coal here has an actual elevation of 1,904 feet, being about 330 feet above the mouth of the branch (1010). The coal shows an upper bench of 6½ inches, then a parting of mixed coal and shale of 7 inches, 2½ inches of clay, 1 foot of coal, 2 inches of black clay, and a bottom bench of 2 feet 6 inches; the floor is of dark-drab fire clay. The sample obtained here included from the 2½-inch clay band for 3 feet down, the bottom of the coal being at the time under water. The faces run northeast and southwest. There is a slight dip here to the northwest. Near the schoolhouse on Slater Fork an old opening partly fallen in showed 18 inches of coal, 5½ inches of clay, 2 inches of coal, and 10 inches of clay, with 1 inch of coal exposed above the filling of the mine. Below the coal is 20+ feet of light-brown clay shale; about 20 feet below the coal is a cliff of massive sandstone 40 feet thick. As a somewhat similar cliff with the coal just described on Slater Fork. At this point the upper coal shows a thickness of 43 inches of bright, partly splinty coal with thin, irregular partings but no regular parting. Under it is a sandy fire clay, and over it 2 feet of shale and 1 foot of shaly sandstone with 8+ feet of shale above. On the John Day place on Crummies Creek (1088) was seen a 38-inch coal without partings. Over it were 3 feet of shale to 6+ feet of sandstone. The floor is fire clay. The coal is bright and good looking. The resemblance of this coal to the coal just described on the Benjamin Field place has made it seem possible that it is the same coal rather than the Kellioka coal whose horizon would come nearly to this level.

COALS OF CATRON FORMATION.

WALLINS CREEK COAL.

The Wallins Creek coal was seen at several openings, probably at enough to warrant our asserting that it will yield workable coal at this horizon all through the Martins Fork and Grays Knob ridges. The ridges south of Martins Fork above Cawood are probably not high enough to catch this coal and while indications are that it underlies the portion of Little Black Mountain in this district, it is not certain that it will prove workable there. The following section of this coal measured or reported will show its thickness in this district. On Mahlan or Lower Double Branch of Catron Creek it is opened on the Mahlan Irving place (1003) at an elevation a little above 2,500 feet, and shows a total thickness of 7 feet and 1 inch, including a 12-inch parting of creamy-white fire clay 8 inches from the bottom. The floor is a drab fire clay. The roof is composed of 1 foot of dark-drab clay shale which tends to come down in mining, being overlain by 15+ feet of light-drab and brown sandy shale. An entry has been driven in about 35 feet here on the faces, which run southeast and northwest. Supposedly the same coal has been opened on the Millard Farmer place, on the right-hand branch of Rocky Branch of Slater Fork of Catron Creek (1019), and at this point the coal has an actual elevation of 2,615 feet. As far as could be measured, it showed a thickness of 47 inches with a 2½-inch parting 20½ inches from the top. It is reported as being much thicker. The sandstone outcrops a short distance above the coal, but neither the roof nor floor was seen. On the G. F. Farmer place, at the head of Farmers Branch of Slater Fork (1022), this coal was opened at a barometric elevation of 2,640 feet, which shows a top bench of coal 15 inches thick; then a parting of 20 inches of bone coal and clay, of which the upper half is full of coal streaks one-fourth inch thick; then 29 inches of coal, including a 3-inch band 2 inches from the top, which is soft and is mined. Below that are 3 inches of very hard nearly black bone, which forms the floor of the mine. Below that is light-yellow fire clay 4 inches thick. The roof is shale 12 feet thick, with sandstone over it. It is reported that under the coal exposed in the opening are two benches, thought to be 15 inches thick, there being reported to be 6 feet of coal running in the whole seam. The faces run northeast and southwest. At this opening a number of specimens were obtained of *Sphenopteris tenella* Brongn., reported by Mr. David White as a type common in the lower Kanawha formation. Two measurements were obtained of a very thick coal in different branches of

Mill Creek. This coal was supposed to be the Wallins Creek coal. At one point the measurement gave a total thickness of 9 feet 10½ inches, including a 1-inch parting 4 inches from the top and 5½ inches of parting 51 inches lower down, and a 1-inch parting 4 inches below that (1025). At another exposure the coal showed a thickness of 9 feet 5½ inches. This showed 1½ inches of bone 5 inches from the top, 2 inches of bone 3 feet lower down, 7 inches of clay 14 inches below that, with 4 feet of coal in a lower bench, as far as it could be exposed. The roof here is a clay shale 15+ feet in thickness. At the first of these exposures the coal has an actual elevation of 2,482 feet and lies 340 feet above a sandstone which makes a waterfall in the creek bed where two principal forks of the creek come together. The upper coal in the first opening shows hard streaks in the upper bench, while the lower bench is softer, showing some brownish streaks with thin plates of bony coal. The two analyses obtained at the first of these openings are of the 51-inch bench and of the coal below the 5½-inch parting. In John R. Proctor's report on this region he gives a section of this coal on Little Branch of Martins Fork which almost exactly resembles the section obtained on Lower Double Branch. It shows a total of 8 feet 7 inches, including a 7-inch fire-clay parting 15 inches from the bottom. Messrs. McCreath and d'Invillier's section of the lower of the two coals discovered by them in Grays Branch on Grays Knob gave a total thickness of 9 feet 1 inch, including a 3-inch clay band 28 inches from the top, 11 inches of fire clay 23 inches lower, 3 inches of shale 11 inches below that, and 2 inches of shale 25 inches from the bottom. On Turtle Creek two exposures of coal supposed to be at this horizon were found near the head. One of these gave the following section: Coal, 15½ inches; clay, three-fourths inch; coal, 8 inches; shale, one-half inch; coal, 3 inches; clay, 1 inch; coal, 4 inches; clay, 1½ inches; coal, 7 inches; clay, 2 inches; coal, 3½ inches; shale, one-half inch; coal, 4 inches. The coal is overlain by soft clay and underlain by a fire clay. The sample obtained at this opening included from the top of the 15½-inch bed to the bottom of the 7-inch bench, so that it included all told 3¾ inches of parting, probably none of which could be separated in actual mining. The entry here runs S. 20° E. on the butts. The other opening showed coal, 2 inches; clay, 1 inch; coal, 26 inches; clay, one-half inch; bony coal, one-half inch; coal, 11 inches; clay, 1½ inches; coal, 13 inches; bony coal, 1 inch; coal, 3 inches. This opening has an elevation of 2,443 feet. Both openings are on the Taylor Low farm. Above the coal numerous fragments of coarse grit occurred which are supposed to have come down from the Jesse sandstone. These were followed up the hill, but no ledge in place was found. They appeared to come from about 300 feet above the coal, a fact which suggested the presence of the Jesse sandstone at that height above the coal, and at an interval which corresponds closely with the interval between the Wallins Creek coal and Jesse sandstone in the Wallins Creek district.

The quality of the Wallins Creek coal was shown by the following analyses:

Analyses of Wallins Creek coal, Martins Fork district.

Constituent.	A.	B.	C.	D.	E.	F.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	1.860	2.320	1.858	1.892	2.910	4.708
Volatile hydrocarbons	36.000	40.150	37.212	35.628	33.610	34.285
Fixed carbon	49.804	50.145	54.125	54.140	45.195	48.909
Ash	11.290	6.590	5.700	7.620	17.520	11.270
Sulphur	1.046	.795	1.105	.720	.765	.828

A. Mahlan Irving place, Lower Double Branch of Catron.
B. G. F. Farmer place, Farmers Branch of Slater Fork.
C. Upper bench of coal on Mill Branch on Henry Neal place (1026).
D. Lower bench on Mill Branch, Henry Neal place (1026).
E. Taylor Low place on Turtle Creek (1026).
F. W. McDonald Hall place on Grays Branch of Martins Fork.

All analyses were by A. S. McCreath; samples from A to E, inclusive, were collected in 1902 and 1903. F was collected by McCreath and d'Invilliers. These analyses show this coal to run high in ash, as might be expected of such a thick coal. Some of the samples indicate an average amount of sulphur, while some run above the average. It is below the average in proportion of fixed carbon. On the whole, it would appear to yield a coal in quality a little below the average of the better coals of this district; and in general this coal may be counted upon to yield quite a large percentage of workable coal, and probably can be worked economically in connection with operations upon the Harlan or Kellioka coal, which lies near the foot of the hill.

SMITH 11-FOOT COAL.

This coal was not seen, but is reported by McCreath and d'Invilliers as occurring on W. McDonald Hall's land on Grays Knob. They say of this coal that it "is opened 90 feet vertically higher and immediately above the last-named development [Wallins Creek coal], and shows an enormous thickness. * * * This bed is here about the same [1,200 feet] elevation above the river and cliff sandstones, and is, moreover, about 400 feet beneath the fossil limestone." They assume that this coal was the same as the Wallins Creek coal (called by them Dean coal), but the stronger resemblance of the lower coal to our own sections of what we thought was Wallins Creek coal has led us to assume that this upper coal is above the Wallins Creek coal, and for reasons stated in the chapter on general stratigraphy—mainly its relationship to the Cawood and Slater sandstones—we have assumed that it corresponds to the 11-foot coal on the Granville Smith place at the head of Puckett Creek. It can not be said that much certainty exists in regard to this correlation, particularly as we did not ourselves see the two coals and can not be entirely sure that the one coal that we did see corresponds to the lower of these two coals. They gave the following section of this coal (1110): Shale roof; coal, 5½ inches; knife-edge parting; coal, 3 feet 3 inches; fire-clay parting, 8 inches; coal, 1 inch; shale, 1 inch; coal, 5 inches; shale, one-eighth inch; coal, 7½ inches; shale, 2 feet 4 inches; coal, 5 feet 7 inches; total, 13 feet 6 inches. Two analyses were obtained of this coal, of which the first included the 3 feet 8½ inches above the 8-inch parting; the second included the 67-inch bottom bench. These gave as follows:

Analyses of Smith 11-foot coal on Grays Knob.

Constituent.	A.	B.	Constituent.	A.	B.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Moisture	8.906	4.362	Sulphur	.571	.532
Volatile combustible matter	35.734	35.908	Ash	7.630	5.910
Fixed carbon	47.159	53.288			

They say of this coal that "the analyses of the two coals do not show any material difference except in the percentage of water, that in the upper bench, or No. 1, being very high and showing an abnormal weathering of the coal. The upper bench carries a small knife-edge of slate at 5½ inches from the top, and the coal was very soft, pulpy, and badly weathered. The lower bench is 5 feet 7 inches thick, holding thin knife-edges of slate at 3, 18, and 40 inches from the top, though all of these binders were included in the samples, owing to the difficulty in separating them in regular mining; yet the percentage of ash is exceedingly low. Indeed, both analyses are very favorable. * * * The bottom bench of coal presented an excellent appearance, being much firmer than the upper bench, though still soft, but apparently suitable for coking."

As no coal was found at this horizon anywhere else in this district we are not prepared to assume that coal of this thickness or possibly even of a workable thickness will underlie the hills at this level.

The old State reports give sections of three coals on the James Howard place on Martins Fork. These were not located in the field. The upper of these coals is reported in one place as 250 feet above drainage and described as 50 inches thick, with a 1-inch parting 5 inches from the top. The next coal below is reported as 250 feet lower, and is 5 feet 8 inches thick without partings. One report describes it as "being found at the base of the hills," or in another place as "at the base of Cumberland Mountain." From these notes it was judged that the coals occurred on Martins Fork above Smith. The upper coal agrees exactly in its section and elevation with what we have called the Harlan coal on the F. S. Hensley place on Wilder Branch of Martins Fork (1056). If the early data were obtained from this locality or from the same coal in this general region, they indicate that a coal had been found in a stratigraphic position just above the base of the Cawood sandstone having a solid thickness of 5 feet 8 inches. Ten feet below it there is reported: Coal and shale 15 inches; coal, 25 inches; shale, 6 inches; coal, 10 inches; shaly coal, 4 inches; coal, 4 inches. From its interval below the 50-inch coal it would appear that this lowest coal would come immediately above the Cawood sandstone. The uppermost of the coals given yielded the first of [illegible] following analyses. [illegible] The analyses [illegible] samples [illegible] December 12, 1896.

[illegible]

[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	.643
[illegible]	[illegible]		

[illegible] dark-salmon color and that of [illegible] color. The [illegible] described [illegible] information of the exact location of this section, [illegible] coals.

SUMMARY.

[illegible] *[illegible]*

[illegible]	30
[illegible] feet	40
[illegible]	6—
[illegible] feet	4
[illegible] do.	25
[illegible] do.	30
[illegible] do.	13½
[illegible] acres	20,000
[illegible] estimated tons	165,000,000

	Walins Creek.	Kellioka.	Harlan.	Other coals.
[illegible] above tide feet	2,500	[illegible]	[illegible]	----------
Thickness:				
Greatest do.	[illegible]	[illegible]	----------	13½
Average do.	7¾	4½	----------	----------
Least do.	5¼	[illegible]	----------	----------
Average thickness of workable coal do.	6+	5¼	4	3
Number of measurements	7	9	24	9
Area of seam acres	3,000	5,000	18,000	3,000
Total coal per acre tons	12,500	7,500	6,560	----------
Available coal per acre do.	8,000	6,000	5,500	4,000
Coal available in district do.	24,000,000	30,000,000	99,000,000	12,000,000

STRUCTURE.

Over the part of this district lying between Catron Creek and Slater Fork on the west and Martins Fork on the north and east the elevation upon the Harlan coal indicates that the rocks lie very nearly horizontal, or if there are local dips they are so balanced as to leave no general dip. The calculated elevation of the Harlan coal just above the mouth of Crummies Creek suggested a slight dip toward the east at that point. It is possible that the same condition of flatness holds true in Crummies Ridge between Turtle Creek and Crummies Creek. South of Crummies Creek and Martins Fork the influence of the folding of the Cumberland Mountain is felt and the rocks show a rise to the south, though this does not become pronounced until Cranks Creek is reached. Along Martins Fork above Smith post-office the high dips of Cumberland Mountain are sometimes seen on the north side of the fork. At Hurst, on Timber Ridge Branch, on the contrary, there is a fairly decided southward dip toward Martins Fork from the north. The dips of the rocks in the Cumberland Mountain are quite variable in this district and in a few places are overturned. Through the flat area first described the Harlan coal is found at just about 1,600 feet. Southwest of Slater Fork there is a fairly rapid rise to the south, but this does not continue probably through the mountain, as the coals on the Martins Fork side of Martins Fork Ridge are but little higher than on the north side of the ridge.

UPPER PUCKETT DISTRICT.

GEOGRAPHY.

This district includes the ridges between the Lower Puckett district on the west, the Wallins Creek district on the north, and the Martins Fork district on the east. In it rise Puckett Creek, Wallins Creek, Catron Creek, Brownies Creek, and practically Martins Fork. Of these Puckett Creek headwaters occupy the largest area, and in all probability should mining be undertaken in this district the coals here would first be attacked from the Puckett Creek side, as transportation would be down Puckett Creek. The name Upper Puckett Creek district has, therefore, been applied because of this fact and the further fact that on the headwaters of Puckett Creek was exposed one of the best sections of coals, if not the best section, in the Black Mountain part of the field. Ridges have the same general character, narrow and irregular crests, and the same general height as in the two preceding districts. However, as the headwaters of several of the creeks occur in this district, a larger share of the coal proportionally is found here than in other districts where the valleys have been cut deeper and have been more or less widened. The coal of this district can probably best be reached by railroad branches up Puckett Creek, but it can also be reached by branches up Brownies, Wallins, Catron, or Martins Fork. The dip being in the main to the north or northwest suggests that Brownies Creek and Martins Fork would not be favorable points for mining upon the coal. Puckett Creek is further favored by lying in a slight transverse syncline.

STRATIGRAPHY.

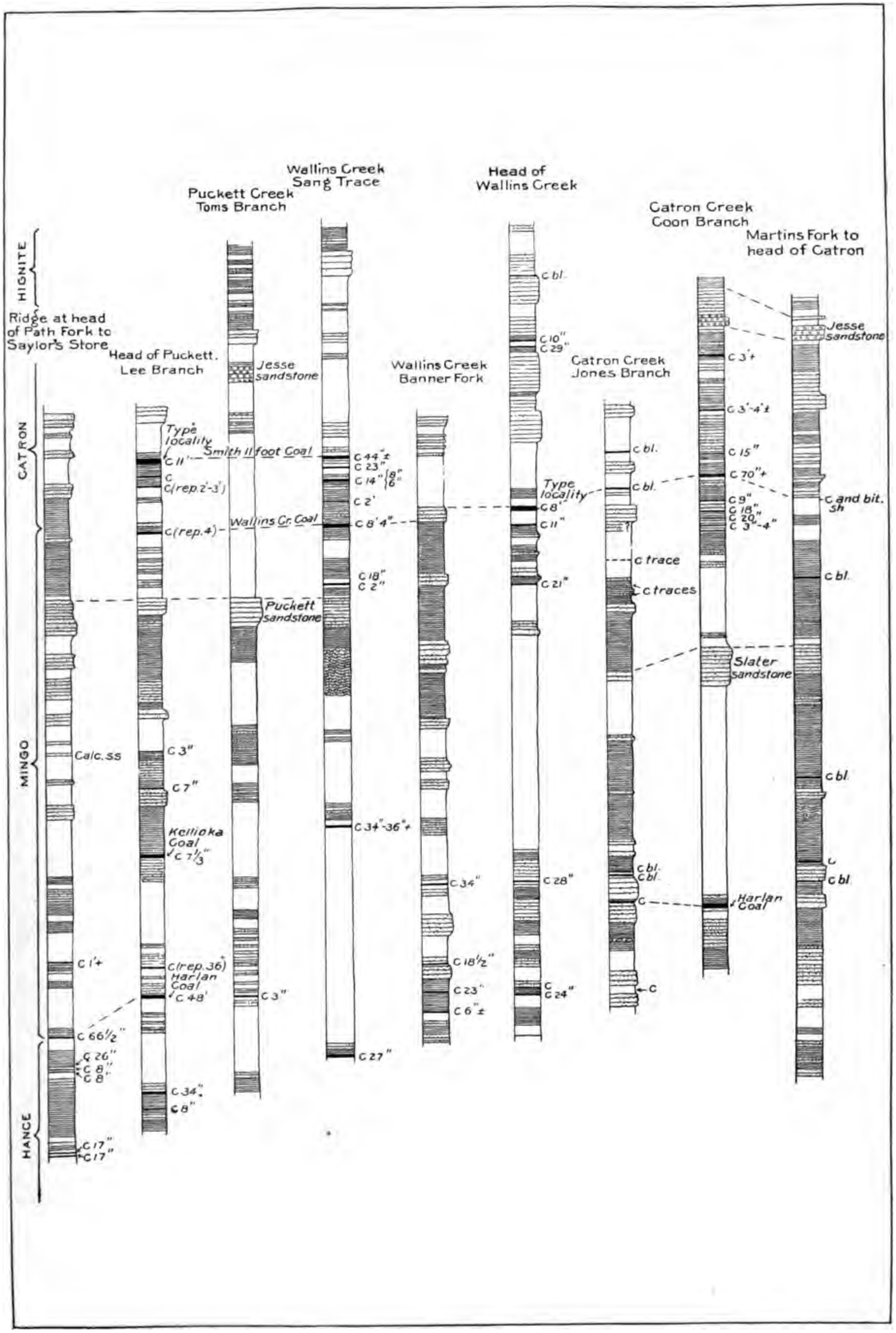
The relations of the coals of this district are best seen in Lee Branch of Puckett Creek. The following skeleton section gives the coals and their intervals:

Section showing coals and intervals on Lee Branch of Puckett Creek.

	Ft.	in.
Interval from top of ridge	110	0
Coal, Smith 11-foot	11	0
Interval	20	0
Coal (?)		0
Interval	20	0
Coal, reported	2–3	0
Interval	100	0
Coal, Wallins Creek (?)	3	8
Interval	140	0
Sandstone, Puckett	30	0
Interval	280	0
Coal		3
Interval	80	0
Coal		7
Interval	140	0
Coal, Kellioka (?)	7	3
Interval	230	0
Coal, reported	3	0
Interval	50	0
Coal, Harlan-Hance	4	0
Interval	200	0
Coal, Puckett	2	10
Interval	30	0
Coal		8

It can not be asserted with entire certainty that the correlations in the above section are correct. An attempt was made to trace the Puckett sandstone from its more typical locality on Jackson and Reynolds mountains into this region, and it would seem to be fairly successful, but the fact that other sandstones at some points make prominent cliffs produces some doubt as to the correctness of the final result. Around the head of Puckett Creek the sandstone here called "Puckett" is quite distinct and makes cliffs at a number of points. If this be the Puckett sandstone, the 44-inch coal occupies about the position assumed for the Wallins Creek coal, and the Smith 11-foot coal is about the correct interval above that to correlate with the 3- to 4-foot coal at 150 feet above the Wallins Creek coal in the Wallins Creek basin. Again the interval from the Puckett sandstone down to the Smith 4-foot coal agrees with the interval from that sandstone down to the Hance coal, or approximately 800 feet. Again the interval from the 4-foot coal to the 7-foot coal agrees with the interval between the Harlan coal and the Kellioka coal, while the interval between the 4 foot coal and the 34-inch coal corresponds with the interval between the Hance coal and the Puckett coal.

The first section on Pl. XXXI, opposite, is a section from the top of the ridge at the head of Lick Branch of Path Fork of Puckett Creek down to the gap at the head of Black Mountain Branch; then down the road to Brownies Creek, near Lee &



COLUMNAR SECTIONS, UPPER PUCKETT DISTRICT.

Scale: 1 inch=300 feet.

The fifth section is a section of the rocks on Banners Fork of Wallins Creek. Coal was seen only near the mouth, so that the stratigraphy of the upper part of the section was left somewhat in doubt. Four coals were noted in the lower part of the section, which had a thickness of 2 feet 10 inches, 1 foot 6 inches, 1 foot 11 inches, and 6 inches, respectively, beginning at the top, with intervals of 160 feet, 60 feet, and 40 feet. The next section was obtained at the head of Wallins Creek, and shows the Wallins Creek coal typically developed. This section gives:

Section showing coals and intervals on Wallins Creek.

	Ft.	in.
Interval, mostly sandstone	110	0
Sandstone, Reynolds (lower part ?)	60	0
Interval, mainly sandstone	80	0
Coal		10
Interval	15	0
Coal	2	5
Interval	10	0
Sandstone, massive, Jesse	80	0
Interval, shales and shaly sandstone	40	0
Sandstone, massive	60	0
Interval	140	0
Coal, Wallins Creek, type locality	8	0
Interval	30	0
Coal		11
Interval, shales and sandstone	125	0
Coal	1	9
Interval	90	0
Sandstone, Puckett (top)	10	0
Interval	510	0
Coal	2	4
Interval	220	0
Coal bloom	......	
Interval	10	0
Coal	2	0
Interval	80	0
Coal, just above mouth of Banners Fork	1	0

The next section was obtained on Jones Branch of Catron Creek, and in it no coals were measured except the Harlan coal and the Pansy coal, both obtained from openings on Catron Creek.

The next section gives the coals and rocks on Coon Branch of Catron Creek. Here again the Wallins Creek coal is well developed and a 3- to 4-foot coal at the same interval above it as the 44-inch coal on Trace Fork, which has been assumed to be the equivalent of the Smith 11-foot coal. The Harlan coal near the base of this section is from the same opening as that in the preceding section. The intervals and coals of this section are as follows:

COALS.

As shown by the columnar sections already given, we may count upon workable coal at at least four horizons—the horizon of the Smith 11-foot coal, the Wallins Creek coal, the Kellioka coal, and the Harlan coal—with possibility of workable coal at the horizon of the Puckett coal. Of none of these can it be asserted that they will yield a workable thickness over all of the area underlain by them. The Harlan coal and the Wallins Creek coal give the best promise as far as present data go. Probably the only coals seen of the Hignite formation were two at the head of Wallins Creek. One of these, which measured 29 inches, came immediately above what was considered the Jesse sandstone, whose top marks the bottom of the Hignite formation. This would occupy about the position of the Lower Hignite coal if our correlations are correct. Fifteen feet above it was seen a 10-inch coal which would come in the position of the Upper Hignite coal of Log Mountains. As neither of these coals is workable, the question of their correlation is a minor one. One hundred and forty feet above the upper of these coals a coal bloom was seen that suggested the outcrop of a rather thick coal. With these exceptions no coals seen in this formation were so exposed that their sections could be measured.

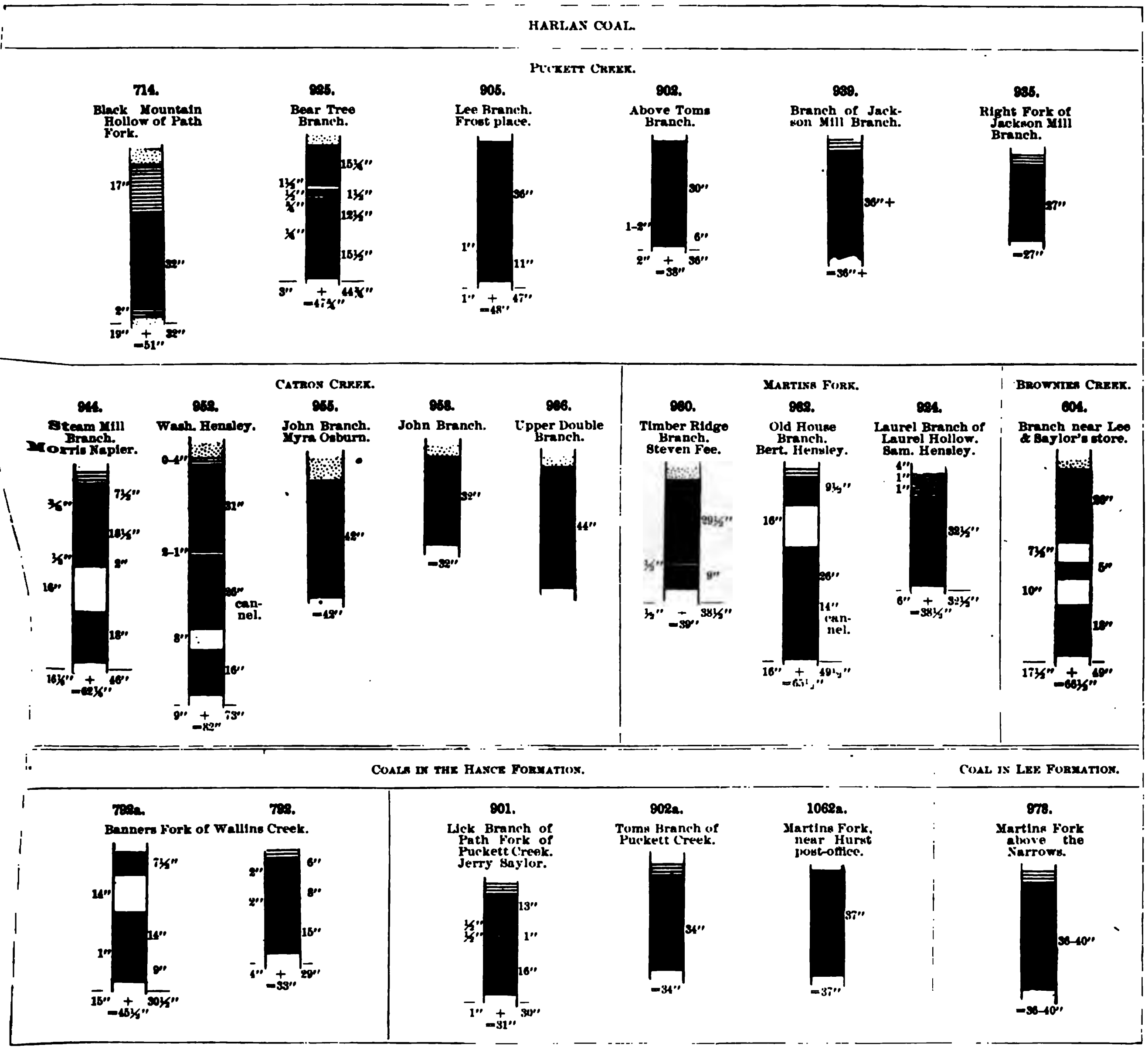
COAL OF LEE SANDSTONE.

One or two coals have been found on the upper part of Martins Fork above "The Narrows." One of these (978) shows a thickness of 36 to 40 inches under from 8 to 10 feet of dark-blue shale. The coal appeared to be good and very hard. It has a fire-clay floor. Another coal of unknown thickness was found higher up. The stratigraphic position of these coals in the formation could not be determined. At this point the rocks are lying nearly horizontal, this being a part of the monocline of Cumberland Mountain, in which the strata having been turned up at a high angle in the north face of Brush Mountain, then turn and extend across the headwaters of Martins Fork with very little dip, being slightly upturned again as they approach the escarpment at the Butts of the White Rocks. On account of this position of the rocks it is possible that this or any thicker coal that may be found in this region may yield a small body of workable coal. On account of the pressure and movements to which it has been subjected such coal is apt to be, as in this case, very hard or else badly broken up, yielding little lump coal.

COALS OF HANCE FORMATION.

On account of the elevation of the drainage in this district, there are in this district few exposures of the coals of the Hance formation. Those on Wallins Creek have in the main been discussed under the heading "Wallins Creek district," as it was more convenient to consider them at that point in connection with other outcrops of the same coals in that district with which it was thought they could be correlated. Two of these coals are shown on Pl. XXXIV, page 196 (792, 792*a*). On Lee Branch of Puckett Creek a 34-inch coal without partings of shale to sandstone and below it 2 inches of shale to sandstone (714). On Bear Tree Branch of Puckett Creek (925) the coal shows a thickness of about 4 feet. This includes one-half inch of bony coal 15¼ inches from the top, underlain by 1½ inches of clay, then three-fourths inch of clay 1½ inches lower, and a ¼-inch clay parting 15½ inches from the bottom. The roof is a sandstone and the floor a bluish-gray clay. The coal here has an elevation of 1,734 feet. On Lee Branch of Puckett Creek this has been opened on the Granville Smith, or, as it is now, Frost place, where it has long been known as the Smith 4-foot coal. It shows a total thickness of 4 feet with a 1-inch bone parting 11 inches from the bottom. Thin clay streaks one-fourth inch or less in thickness were noted at 14½ inches from the top, 1½ inches lower, and 20 inches below that. Below the coal is 1 inch of clay and 2 inches of coal, then fire clay. Above the coal is clay shale and massive sandstone a short distance above. A sample obtained from this bank was too badly weathered to give a fair idea of the quality of the coal. On Puckett Creek above Toms Branch about 200 feet above the creek bed at the mouth of the branch this coal shows a thickness of 3 feet with 1 to 2 inches of clay 6 inches from the bottom. Sandstone outcrops immediately above and below the coal (902). On a branch of Jackson Mill Branch of Puckett Creek this coal showed a thickness of 3 feet plus, the bottom not being visible. The coal here was solid and good and reported to burn well by those who have used it (939). This is on the James Shackleford place. On a side climb from the right-hand fork of Jackson Mill Branch of Puckett Creek this coal showed a thickness of only 27 inches. It has over it 4 feet of sandy shale grading up into shaly sandstone, with below 12 inches of fire-clay floor to a hard sandstone. At both of these openings on Jackson Mill it lies between two sandstones as at the type locality around Harlan. At the opening on the right-hand fork (935) the coal is bright and firm with faces running from N. 50° E. to S. 40° E. The roof flakes down. On Catron Creek this coal shows on Steam Mill Branch on the Morris Napier place just above Pansy (944). It is badly broken up by a 16-inch parting, the lower bench being 18 inches thick, and the upper bench, which is about 30 inches thick, has a ⅜-inch parting 7½ inches from the top and a ½-inch parting 2 inches from the bottom. The roof is shale. At the next opening on the Washington Hensley place, opposite the mouth of John Branch (952), this coal shows an unusual thickness. There are three benches, the upper of which measured from 2 feet to 2 feet 7 inches; then comes a grayish-clay parting from 2 inches to 1 inch in thickness, then a little bench from 1 foot 10 inches to 2 feet 2 inches in thickness. The lower 8 to 14 inches of this bench is a good cannel coal with conchoidal fracture. Below an 8-inch parting of clay there was seen at the mouth of the drift 1 foot to 1 foot 4 inches of coal, also a cannel. The roof is a brown shaly sandstone for 2 feet, with 8 feet plus of sandy shale above. Between the sandstone and the coal a little shale is sometimes seen ranging up to a thickness of 4 inches. The faces run N. 40° W. The sandstone roof appears to be of good quality. The coal here is 150 feet above the creek at an elevation of 1,710 feet and shows a slight eastward dip.

On John Branch, to the south of the last opening, the Harlan coal has been opened on the Myra Osburn place (956). Here it showed 52 inches of coal without partings, and a sandstone roof. The coal has an excellent roof here. Its elevation



COAL SECTIONS, UPPER PUCKETT DISTRICT.

Scale: 1 inch=5 feet.

one sample gave a high percentage of sulphur. The proportion of fixed carbon ranges from quite low to high, with an average about medium for this district. The percentage of volatile matter is usually rather above the average, in one case running over 40 per cent. These facts suggest a coal of good quality with rather a high ash, probably due to the fact that the samples included small partings in many cases.

As a result of its low position in the mountain, coming as a rule fairly near drainage, this coal underlies a large portion of the district, and should it prove to be as a whole no worse than may be judged from the sections already obtained, it ought to yield a large amount of workable coal. Its elevation at the east is about 1,600 feet, but it tends to rise to 1,700 feet on Puckett Creek, and in places on Martins Fork, where it is brought within the influence of the Powell River anticline, it reaches an elevation of 1,800 to 2,000 feet.

McCreath and Peter both give analyses of the upper and lower parts of the Washington Hensley bank separately as given below; the A and C analyses are by McCreath from samples obtained by McCreath and d'Invilliers; B and D are by Peter from samples obtained by R. C. B. Thruston; A and B include the coal down to the top of the 1 foot of cannel; C and D include the 2 benches of cannel 1 foot thick and 16 inches thick.

Analyses of coal at G. W. Hensley place on Catron Creek.

Constituent.	A.	B.	C.	D.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	3.602	2.50	1.284	0.80
Volatile hydrocarbons	35.293	31.90	40.656	37.30
Fixed carbon	55.412	60.80	47.723	54.90
Ash	5.110	3.80	7.960	7.00
Sulphur	.583	.438	2.367	1.925

These analyses show the cannel coal to be of excellent quality as regards its percentage of ash, but to have such a high percentage of sulphur as to render its workability doubtful. For ordinary steam purposes, worked in connection with the bituminous coal above, it may prove satisfactory.

KELLIOKA COAL.

The type of this coal for this district was on the Hiram Hensley place on John Branch of Catron Creek (959). The coal here shows a total thickness of 7 feet 1½ inches, including 6 inches of clay 17 inches from the top, 3½ inches of dark-drab clay 17 inches lower, 8 inches of drab clay 3½ inches below that, and a bottom bench of coal 40 inches thick, including a 1-inch parting of black clay 1 foot from the bottom. The analysis of this coal included only the bottom bench practically 3 feet thick. Above the coal is 6 feet plus of drab shale. The faces here run N. 40° E. This coal lies at an elevation of 1,957 feet, or about 300 feet above the branch. One hundred and fifty feet higher, the massive total thicknesses up to 7 feet or more in most cases, the portion of them that could be worked ranges from about 2½ feet to 5 feet, or 6½ feet in the case of the exposure on Lee Branch of Martins Fork. On the whole, however, it may be doubted if this coal will yield on an average more than about 3 feet of coal that can be economically worked.

The quality of the Kellioka coal is indicated by the following analyses:

Analyses of Kellioka coal in Upper Puckett district.

Constituent.	A.	B.	C.	D.	E.	F.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Moisture	1.80	1.844	1.630	1.534	1.74	1.868
Volatile hydrocarbons	34.20	38.506	38.990	37.106	33.32	39.232
Fixed carbon	60.10	54.584	54.222	51.298	59.24	54.376
Ash	3.90	3.940	4.030	8.720	5.70	3.300
Sulphur	.917	1.126	1.128	1.342	1.034	1.224

A. Seven-foot coal, old Grandville Smith place, Lee Branch of Puckett Creek; sampled by R. C. B. Thruston, October 12, 1886. Analysis by Robert Peter.

B. Same coal, same locality; sampled by McCreath and d'Invilliers, 1888. Analysis by A. S. McCreath.

C. Same coal, same locality; sample obtained in August, 1902. Analysis by A. S. McCreath.

D. Lower part of bed 3 feet thick from Hiram Hensley Branch, John Branch of Catron Creek; sampled by R. C. B. Thruston, July, 1887. Analysis by Robert Peter.

E. Same locality; sampled August, 1902; analysis by A. S. McCreath.

F. William Lee place, Laurel Branch of Martins Fork, includes only the lower 44 inches of coal; sampled August, 1902; analysis by A. S. McCreath.

These analyses indicate the coal to have an average quantity of ash, but to be considerably above the average in sulphur, and from fair to high in fixed carbon, indicating a good coal for steaming purposes.

Forty feet above the Harlan coal a cannel coal has been opened upon John Branch of Catron Creek that has attracted some attention. It was not opened when visited in 1902. McCreath and d'Invilliers report the coal as 4 feet 6 inches thick, of which the top, 1 foot 9 inches, is bituminous coal and the bottom, 2 feet 9 inches, cannel. McCreath obtained the following analyses of the upper bituminous bed (A) and of the cannel bed (B); the third analysis (C) is of a cannel-coal sample collected by Mr. R. C. B. Thruston and described as "8 miles from Mount Pleasant (Harlan), at the head of Catron Creek of Martins Fork. * * * Sample from 22-inch seam in bed containing 3 seams, 2 of stone coal, severally 18 and 6 inches thick, separated by a 2-inch shale parting; 120 feet above drainage, a dull, gray-black cannel coal, irregularly laminated." As the description indicates that it was not in John Branch of Catron, we have supposed this to be the same bed from some neighboring point on the main branch of Catron Creek. Its analysis has, therefore, been inserted at this point.

fire clay, underlain by coarse sandstone. On Sang Branch of Wallins Creek (767) this coal shows a thickness of 44 inches without partings. On Coon Branch of Catron Creek a very poor exposure of it indicated a thickness of from 3 to 4 feet (771). At this point, however, it was badly weathered, and it was not possible to get a good section (967). It is of course possible that the coal at the last two exposures represents only part of the coal as exposed at the Smith place, the 12-inch parting possibly having thickened so as to separate the two main benches. On Trace Fork a 23-inch coal was found about 15 feet below the 44-inch coal, which may be a lower bench of the Smith 11-foot coal, though, as a sandstone bed comes between the two, it would hardly seem probable. We must therefore consider that if this correlation is correct, the 11-foot coal on Lee Branch is simply a local thickening of a bed which normally runs from 3 to 4 feet in thickness. Thirteen feet of coal on Grays Knob, thought to lie at the same horizon, would be a similar instance of a local thickening, and it would not be unexpected under these circumstances if a similar thickening should be found at other points.

The following two analyses of this coal at the type locality include only the upper bench of coal. The first analysis was from a sample obtained in 1902, the analysis being by A. S. McCreath; the second analysis from a sample obtained October, 1886, from Mr. R. C. B. Thruston, is by Peter. The sample for the last analysis was air-dried.

Analyses of Smith 11-foot coal, Lee Branch of Puckett Creek.

Constituent.	A.	B.
	Per cent.	*Per cent.*
Moisture	2.500	4.00
Volatile combustible matter	37.010	31.00
Fixed carbon	49.680	56.00
Sulphur	.990	1.027
Ash	9.820	9.00

The coke obtained was fair but somewhat granular in structure. These analyses show this coal to be of fair quality, though carrying a large percentage of ash and a small proportion of fixed carbon. The moisture percentage indicates that the coal was more or less weathered. It may be safe to figure on this coal showing a thickness of between 3 and 4 feet under most of the area with a greater thickness locally, which can hardly be considered in figuring the value of the coal, as it is very apt, as in the section on Lee Branch, to show partings when thick which will reduce the actually workable coal to nearly the lower figure.

CORRELATION OF COALS OF CATRON FORMATION.

In this district the Catron formation shows at least five coals, of which two may be considered workable. The two workable coals are here about 150 feet apart. The lower of them has been considered as at about the horizon of the

Fork or the right-hand fork of Wallins Creek there appears to be little change in elevation. The coals on Coon Branch of Catron Creek have an elevation of 2,625 feet on the right-hand fork and 2,601 on the left-hand fork. At the extreme head of Catron Creek the same coal is estimated to have an elevation of a trifle over 2,800 feet and a little less at the head of Puckett Creek.

CORRELATION OF COALS.

By David White and George H. Ashley.

While of very minor economic value, the question of the correspondence of the coals of the different fields is one of great interest to mining men. Where coals are highly persistent, such correlations may be of high value, as it may be possible to predict ahead the quality as well as thickness and reliability of any given coal. In this field the coals seem to be fairly persistent in respect to thickness and quality, but hardly enough so that the characteristics of the coals at one place will serve to identify the same coals elsewhere, or to prove useful in predicting their value.

The following chapter, while written by Mr. Ashley, is based almost wholly on data obtained by Mr. White. It has already been stated that all the rocks exposed in this basin are believed to be of Pottsville age. In the early geologic work in this part of the Appalachian field it was supposed that what is here called Lee represented all of the Pottsville of this region. Later discovery of Pottsville plants in the upper part of the Norton formation in the Bristol quadrangle led to the conclusion that the top of the Pottsville must be placed much higher than was at first thought possible.

In his Geology of the Virginias, 1884, Mr. W. B. Rogers makes the following classification of the Coal Measures:

Lower barren group, XIV.
Lower coal group, XIII.
Great conglomerate or conglomerate coal group, XII (Pottsville).
Greenbrier shales, XI.

In his coal report for the West Virginia Geological Survey (1904), Prof. I. C. White, following in the main his Bulletin 65, United States Geological Survey, 1891, uses the following names for the corresponding groups:

XVI. Dunkard.
XV. Monongahela.
XIV. Conemaugh
XIII. Allegheny-Kanawha.
XII. Pottsville.
XI. Mauch Chunk red shale, Greenbrier, or Mountain limestone.

Creek coal and the Lower Hignite coal appear to be distinctly referable to the Lower Kanawha of West Virginia. The Bryson formation appears to be included in the time of the Upper Kanawha, judging from material collected at the horizon of the Red Spring coal, which will probably fall in the upper part of the Kanawha formation, and not far from the Winifred and Coalburg coals.

In Mr. Campbell's report on the Big Stone Gap coal field, 1893, he gives the following table of formations:

	Feet.
Harlan sandstone	880
Wise formation	1,270
Gladeville sandstone	100
Norton formation	1,280
Lee conglomerate	1,500

Assuming that the top of the Lee has been drawn at the same horizon at Cumberland Gap as at Big Stone Gap, and that Mr. Campbell's measurement of the Norton is correct, his Gladeville sandstone should come about at the horizon of the Puckett sandstone of the Cumberland Gap field, as that sandstone has been estimated at about 1,350 feet or a little less above the top of the Lee. It is possible that the top of the Lee at Big Stone Gap was drawn at the top of the Yellow Creek sandstone of this field, in which case the agreement is still closer. On the other hand, taking the position of the Gladeville sandstone as given on upper Clover Fork on Mr. Campbell's map, and McCreath and d'Invillier's description of the sandstones seen along that fork from the edge of Campbell's map to the edge of the map accompanying this report, it would appear that the Gladeville corresponded to the massive sandstone just above or below the Harlan coal. Messrs. McCreath and d'Invilliers thought that the heavy sandstone in the upper valley of Clover Fork could be traced down into the Cawood sandstone just above Harlan court-house. Careful tracing, however, shows that the latter sandstone passes beneath Clover Fork below Jones Branch. In view of the possibility of error in the correlation of the Gladeville sandstone from its typical locality over Black Mountains into Clover Fork and the lack of definite detailed tracing of the sandstones down part of Clover Fork, little reliance can be placed on this last correlation. One or two facts favoring the correlation of the Gladeville sandstone with either the sandstone just above or just below the Harlan coal are, first, the existence of rather heavy coals just above and just below the Gladeville. On Poor Fork, near Poor Fork post-office, there is a coal that locally reaches a total thickness of 16 feet, and at one point shows a 13-foot bench without parting. On Clover Fork this coal just above the Gladeville appears to be thin, but a thick coal, not important eastward, appears just below the Gladeville. If either of these coals correspond with the Harlan coal, the Gladeville would necessarily correspond to one of the sandstones close to the Harlan coal. In the second place, the top of the Gladeville is described as 1,270 feet below the bottom of the Harlan sandstone, which is described as carrying pebbles. If the pebble-carrying horizon of this region—the Jesse sandstone—corresponds with the bottom of the Harlan sandstone of the headwaters of Clover Fork the space from that down to the Harlan coal, which is about 1,200 feet, agrees well with the interval farther east. No accurate measurement from forms that closely resembled the flora at the Mingo mines. Assuming that the coal now mined at Straight Creek is the same as the Jellico, this fact suggests that the Mingo and Jellico coals are the same bed. Another fact tending to corroborate the conclusion is the finding of animal remains in the shales above the McGuire coal a short distance above the Dean coal. According to the interpretation that the Jellico is the same as the Mingo, the Dean is the same as the Poplar Lick or the Wallins Creek coal, and the McGuire coal corresponds with the Klondike. On the other hand, according to a section prepared from Mr. Crandall's report on Whitley and Pulaski counties, the Jellico coal is only 400 feet above the "Conglomerate" or Lee, whereas the Mingo coal has been calculated as over 1,000 feet above. A review of Mr. Crandall's original article reveals the fact that he does not give the exact distance of the Jellico coal above the Lee, the necessary data evidently not having been found. It is evident, however, that he considered its position about the equivalent of the Bennett Fork coal on Bennett Fork. Work done by him on Tackett Creek led him to the same conclusion. With this interpretation the Dean coal occupies the position of the Mingo coal. As tending to corroborate this correlation is the section of a coal 250 feet above the Dean coal on the Ransom Slusher place on the left fork of Straight Creek. It shows as follows:

Section of coal on left fork of Straight Creek.

	Ft.	in.
Coal	1	6
Sandstone		2
Coal	1	1½
Clay		¼
Coal		4½
Bituminous shale		3½
Clay		6

This section certainly resembles the Sandstone Parting bed of the Log Mountains. At this time we are not prepared to do more than suggest those two possible correlations.

There remains to consider the possible correlations with the coals to the southwest. In a section obtained by Mr. White at Big Creek Gap in the southwestern end of the Cumberland Gap coal field, the Rex coal was calculated to be about 175 feet or more above the top of the Lee, according to which bed, in a series of waning sandstones, is selected as the top of the latter formation. At 447 feet above that comes the Kent coal, which on the head of Davis Creek, a tributary of Clear Fork of Cumberland, splits into two or three benches. One hundred and thirty feet below the Kent there is reported a coal, locally called the Blue Gem. By these measurements the Kent coal is 622 feet above the top of the Lee, or about in the position of the Bennett Fork coals; 240 to 250 feet above the Kent coal is a 41-inch coal with two partings in the middle, probably the Rich Mountain coal, with at least three coals in the interval. This would be in the position of the Kellioka coal of the Black Mountains. One hundred feet higher a 4-foot coal is reported on Davis Creek.

The next important coal above this is the Jordan, showing 5 feet of coal with 1 inch of parting 12 inches from the top. This is 200 feet above the 4-foot coal, or correspond with the Upper and Lower Hignite coals in the Log Mountains region. Still above the Block coals about 550 feet are one or two thick coals, one of which may represent the horizon of the Red Spring coal. Still above that 200 feet are thick coals, associated with which is a mixed flora of Kanawha and Allegheny, but still of clearly Kanawha age. If the correlation immediately preceding is correct, this last plant horizon will come at or above the top of the highest strata in the Log Mountains, or in that part of the Black Mountains studied and mapped by us, and as at this horizon the plants indicate still Pottsville age it is evident that all of the rocks in the area studied by us are of Pottsville age.

Provisionally, the Anderson sandstone of the Briceville area is thought to be continuous with the Harlan sandstone of the Estillville area, and both with the Charleston sandstone of the Kanawha region.

EXPLOITATION AND DEVELOPMENT OF COALS.

CHEMICAL CHARACTER OF COALS.

In connection with the description of the coal beds, chemical analyses have been given of the coals, the analyses being made by Mr. A. S. McCreath from samples obtained in 1902 and 1903, or from samples obtained by McCreath and d'Invilliers in 1887, or by Robert Peter, formerly State chemist of Kentucky, from samples obtained by different members of the Kentucky Survey. The analyses by the last analysist were in all cases of air-dried samples, and it is not known whether the samples obtained represented an average of the whole seam or not, though it has been assumed that in most cases at least it did. The analyses obtained in 1902 and 1903, and it is believed also those obtained by McCreath and d'Invilliers in 1887, were obtained by cutting a section of the coal, or of such part as seemed desirable, excluding only such partings as it was thought would be excluded in practical mining. It should be remembered that in the majority of cases these samples were obtained from outcrop coal, in some cases the coal being soft and crumbly, and so badly weathered that it would not make a coherent coke. At the end of the report on the resources of the Cumberland Valley by Messrs. McCreath and d'Invilliers they summarized the analyses of the coals obtained by them, giving a general description of the quality of the coals. They examined and tested the coals in what is now the Big Stone Gap coal field of Lee and Wise counties, Va., then the coals from the head of Clover Fork of Cumberland River to Pineville, and then the coals of the Yellow Creek basin, comprising practically what is included in the area west of Yellow Creek in our study. For the sake of comparison the averages and other data furnished by them of the three districts will be given. The tables as reported exclude the cannel coals. The samples analyzed from the Big Stone Gap district (19 coals) averaged as follows:

Average analysis of coals from Big Stone Gap district.

	Per cent.
Moisture	1.918
Volatile matter	36.449
Fixed carbon	53.815
Sulphur	1.396
Ash	6.432

Of the 6 samples thus grouped the amount of water shown in 4 is less than 2 per cent; in 1 it is between 2 and 3; in 1 it is between 3 and 4. The sulphur in 2 is less than 1 per cent; in 2 it is between 1 and 1½ per cent; in 2 it is between 1½ and 2 per cent. The ash in 1 is less than 3 per cent; in 2 it is between 3 and 5; in 3 it is more than 8.

In discussing these tables they say as follows:

"A comparison of these tables and averages will show the general superiority of the coals tributary to the Cumberland River route; whereas between the two others there is very little difference.

"Perhaps the most striking feature brought out by comparison of these results is the excessive percentage of water in many of the coals along the Cumberland River route, nine of them showing over 4 per cent. This is, doubtless, due in a very large measure to the geographic position of these coals, by which their exposure to the north storms has brought about more rapid weathering and change of physical structure than is the case with the coals on the south side of the mountain divide in Virginia, as well as those but partly exposed to the effects of the elements from the Yellow Creek territory. While this weathering has produced a higher percentage of water in all the coals, which were apparently quite dry, it has likewise probably effected a decrease in the percentage of sulphur and perhaps ash. It will, undoubtedly, prove to be the case upon further developments, but while these coals will be found to carry only a normal percentage of water, they will not show such a marked increase [decrease?] in their percentage of sulphur and ash.

"In the matter of ash, it may be taken for granted that any decrease in this constituent, due to leaching, is fully compensated for by the presence of infiltrated mud, for many of the samples show this feature to a marked extent.

It will readily be seen that the coals as a whole are essentially graded as gas coals; for while undoubtedly the chemical analyses of many of them would serve to indicate coals more adapted for coking purposes, it has not been found possible to say how far such coals would make a marketable coke when subjected to a regular oven test; and their behavior in crucible tests in the laboratory was such as to suggest some doubt as to their proper classification in the coking coal list from their failure to show satisfactory tests. Nevertheless, such negative results may be, and doubtless are, due in a great measure to the fact that practically all of the samples were taken from outcrop and sometimes badly weathered coal; and it is well known that the weathering of coal greatly deteriorates, if indeed it does not entirely destroy, its coking qualities. That this weathering was excessive in many instances there can be no doubt, for the coal was soft and pulpy.

"The general list of analyses will, however, serve to classify them as usually good steam coals, rich in volatile matter, and thus insuring a quick fire and the rapid generation of steam."

Since the above was written the coals of both the Big Stone Gap area and the Yellow Creek area have been developed and coked upon a commercial scale. As far as could be learned, and as far as such coke was seen, it was of good quality, and it is probable that when tested from regularly mined coal the coals of the Cumberland River field will also yield good coke. Nevertheless a comparison of the analyses given with those of standard bituminous coals show that these coals should, as a whole, be classed with the gas coals rather than with the coking coals. In the same report Messrs. McCreath and d'Invilliers give the average analyses of various well-known fuels, which, for the sake of comparison, might be repeated here.

Analyses of standard bituminous coals.

	Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Westmoreland gas coal	1.427	37.521	54.921	0.713	5.418
Pennsylvania gas coal	1.280	38.105	54.383	.792	5.440
Clinch Valley gas coal	1.180	37.398	56.732	.619	5.602
Clinch Valley steam and coking coal	1.152	31.451	57.754	.759	8.884
Cardiff steam coal	2.552	33.123	56.774	1.326	6.225
Connellsville coking coal	1.260	30.107	59.616	.784	8.233
Flat Top coals	1.011	18.812	74.256	.730	5.191

A study of the analyses of coals of the Cumberland Valley district from samples obtained in 1902 and 1903 was made by averaging the analyses of a few of the principal coals. For this purpose the Wallins Creek, the Creech, and Kellioka, the Hance, and the Harlan coals have been selected. The Hance and Harlan coals are supposed to be at about, if not at, the same horizon. The average of the samples of Wallins Creek coal give as follows:

Average analysis of Wallins Creek coal.

	Per cent.
Moisture	3.571
Volatile hydrocarbons	35.679
Fixed carbon	50.796
Ash	9.017
Sulphur	.812

Of the 7 samples from which the above average was obtained. the following are the maxima and minima:

	Per cent.
Moisture	1.858–12.674
Volatile hydrocarbons	29.366–40.150
Fixed carbon	45.195–54.140
Ash	5.700–17.520
Sulphur	.525– 1.105

In the same coals the water in 3 is less than 2 per cent; in 3 it is between 2 and 3 per cent; in 1 it is over 3 per cent. The ash in 5 is between 5 and 8 per cent; in 2 it is more than 8 per cent. The sulphur in 5 is less than 1 per cent; in 2 it is between 1 and 1½ per cent.

The following are the averages in the analyses of 5 samples of Creech coal:

	Per cent.
Moisture	3.038
Volatile hydrocarbons	36.779
Fixed carbon	55.613
Ash	3.850
Sulphur	.719

The same coals gave minima and maxima as follows:

	Per cent.
Moisture	1.350- 5.100
Volatile hydrocarbons	35.270-38.760
Fixed carbon	53.101-57.392
Ash	2.800- 5.840
Sulphur	.608- .913

Of these, 1 has less than 2 per cent of moisture; 1 between 2 and 3 per cent; 2 between 3 and 4 per cent, and 1 more than 4 per cent. Of ash 1 has less than 3 per cent; 3 between 3 and 5 per cent; 1 more than 5 per cent.

Five samples of the Kellioka coal yielded the following average:

Average analysis of Kellioka coal.

	Per cent.
Moisture	1.667
Volatile hydrocarbons	38.324
Fixed carbon	54.053
Ash	4.860
Sulphur	1.074

The same coal gives the following minima and maxima:

	Per cent.
Moisture	1.534- 1.868
Volatile hydrocarbons	37.106-39.232
Fixed carbon	51.288-56.396
Ash	2.140- 8.720
Sulphur	.704- 1.342

All show moisture between 1 and 2 per cent. In ash 1 shows less than 3 per cent; 2 between 3 and 5 per cent; 1 between 5 and 8 per cent; 1 more than 8 per cent. In sulphur 2 show less than 1 per cent; 3 between 1 and 1¼ per cent.

Nineteen analyses of Harlan coal average as follows:

Average analysis of Harlan coal.

	Per cent.
Moisture	1.973
Volatile hydrocarbons	37.553
Fixed carbon	54.692
Ash	4.993
Sulphur	.791

These 19 analyses show the following minima and maxima:

	Per cent.
Moisture	1.314- 6.610
Volatile hydrocarbons	33.510-41.558
Fixed carbon	47.665-57.285
Ash	2.450-14.910
Sulphur	.504- 1.230

A. TIMBER RESOURCES OF UPPER CUMBERLAND VALLEY.

View from mountain top, showing generally forested condition of the basin.

B. VIEW IN FOREST, SHOWING FIRST GROWTH OF TIMBER.

impurities, and in every respect the coal is a valuable one for gas manufacture. Compared with Main Lesmahagow cannel coal represented by 100 (correlated on the basis of a production of 13,000 cubic feet of gas, 1,535.5 pounds of sperm per ton, and having regard also to the value of the secondary products and the cost of the purification of the gas), this coal is equal to 70.17.

"This coal may with advantage be employed for the manufacture of kiln coke, but is better adapted for the manufacture of gas, as the foregoing results show."

Of the Mason (Mingo) seam he reports as follows:

"This is a valuable coal, alike for the production of gas and coke; of the former it yields a large volume of 21.86-candle gas, while for purity and value as a fuel the latter can not be surpassed. The fuel gas contains a very small amount of impurities, and is therefore very easily purified. The coal is fully equal to the finest of English or Welsh coals. Compared with Main Lesmahagow cannel coal, represented by 100, this coal is equal to 69.01. For the manufacture of kiln coke for metallurgial purposes this coal is very well suited, containing, as it does, about the smallest amount of ash and sulphur that I have yet found in a bituminous coal."

Of the Lower Hignite coal he reports as follows:

"This is a very valuable coal of its class for the manufacture of gas and coke; it is easily distilled and yields up a large amount of illuminating matter per ton and affords at the same time 12.12 hundredweights per ton of first-class coke. It is, in short, without one detracting feature. Compared with Main Lesmahagow cannel coal, represented by 100, this coal is equal to 70.25. The coal is better adapted for gas than for kiln coke manufacture."

Of the Bear Creek cannel coal he reports as follows:

"This is a cannel coal of exceptional value, as it is one of remarkable light-giving power and purity, yielding, as it does, a sperm value of illuminating matter amounting to 2,068.69 pounds per ton, while at the same time affording a light and spongy coke of excellent quality. The coal contains a very small percentage of both water and sulphur. Compared with the Main Lesmahagow cannel coal, represented by 100, this coal is equal to 137.11."

In regard to the Bear Creek cannel coal, the following table is published in the mine inspector's report for 1899:

Results of tests of Bear Creek cannel coal.

	Gas per ton of coal, in cubic feet.	Illuminating power of gas, in standard candles.	Volume of gas from one ton of coal, in pounds of sperm.	Coke per ton of coal, in pounds.
Lesmahagow	13,201	34.52	1,562	1,019
Tyne Boghead	13,115	38.22	1,723	1,301
Newbattle	12,461	35.34	1,509	983
Falling Rock	14,210	36.15	1,761.51	1,178
Bear Creek (Log Mountains)	14,630	41.24	2,069	995
Pineville Coal Co.'s (north of Pine Mountain) Boghead	15,805	36.26	1,964.87	1,089
Willaford	15,835	44.55	2,418.68	995

Compared with the Main Lesmahagow cannel coal, represented by 100, Falling Rock cannel is equal to 112.07, Bear Creek cannel is equal to 137.11, and Pineville-Willaford cannel is equal to 148.31. The above analyses are all from reports made by Mr. George R. Hislop, gas engineer, Paisley, Scotland. For comparison with these it may be stated that 1 ton of the famous Breckenridge cannel coal yielded in pounds of sperm, 2,407.

THICKNESS OF COAL.

The two principal factors determining the workability of a coal are its quality and thickness. Of these, the quality is of first importance. The question as to what constitutes a workable thickness in all cases will depend upon the quality to a greater or less extent. Many of the western coals, which are of somewhat lower grade than the Appalachian coals, are not considered workable under an average thickness of 3½ to 4 feet, except in such districts as are not well situated as regards transportation facilities for bringing in the higher-grade coals from the east. On the other hand, where the coal is of unusually good quality, it may be worked down to below an average thickness of 2 feet. Thus in the Illinois field the higher, or, as they are locally called, bituminous coals are seldom worked commercially unless they reach a thickness of 4 feet. The block or semiblock coals of the same field, which are of a slightly better grade, are extensively worked in many mines where the average thickness is not over 3 feet; but as a rule in such mines work is discontinued as soon as the coal has thinned down to from 28 to 30 inches. In contrast with that, the Blue Gem seam, in the Jellico district of Kentucky and Tennessee, which is just being developed, has, it is claimed, an average thickness of only 22 inches, but as it is a very high-grade domestic coal it is found profitable to mine it even with as low a thickness as that. The main "Jellico vein" of the Jellico field is said to have an average thickness of about 39 inches. Again, its excellent quality makes its mining profitable.

One of the large mines in central Pennsylvania is working a coal 2½ feet thick on the average, and this same bed has been worked in this and adjacent mines down to a thickness of 17 inches before mining was stopped. The famous Pittsburg coal bed of Pennsylvania, Maryland, West Virginia, and Ohio, while often having a total thickness of 10 to 12 feet, has a workable thickness of only from 4 to 10 feet, possibly averaging about 7 feet. In this case the bottom coal and the roof coals are not worked. At its type locality in the Ormsby mine, at Twenty-first street, Pittsburg, the total thickness of the coal below the "over" clay is 61¾ inches, including 14 inches of bottom coal, the bottom coal usually not being mined. In the New River field the Quinnimont-Fire Creek coal lies in swamps or basins, in which the coal ranges from 3 to 5 feet in thickness, but such swamps are usually surrounded by areas in which it is very much thinner and in places is wanting altogether. At many of the mines it is worked down to 2 feet. The Sewell coal, in the same field, ranges from a maxima of 5 or 6 feet to 2 feet 6 inches or less going down New River.

From what has been said it is evident that coals of the quality of the coals of this district may be considered to be workable when from 2½ to 3 feet thick, and in exceptional cases may be workable when 2 feet thick. In these figures we are,

of course, considering conditions as they will probably exist in the immediate future. Undoubtedly still thinner coals will be worked at the distant future. Compared with these thicknesses we find the Mingo coal, at present being worked west of Middlesboro, to range from 4 to 6 feet in thickness. The Klondike coal, where being worked, would be pratically 6 feet thick; the Hance coals, in the Hance district, to range from 4 to 5 feet in thickness; the Harlan coal to show usually a single bench more or less nearly 4 feet in thickness, often 1 or more feet of additional coal that may or may not be taken. The Wallins Creek coal, in the eastern part of the field, shows a single bench from 5 to 7 feet in thickness. The other coals, both in the eastern and western district, will undoubtedly show large areas of coal from 3 to 4 feet thick, and probably still larger areas, in which the workable part of the bed will be from 2 to 3 feet thick.

In regard to the volume of coal the figures already given in the body of the text are sufficiently comprehensive and need not be repeated here. It need be only recalled that the Harlan coal in the Harlan, Martins Fork, and Upper Puckett districts has been computed to show an area of almost 100 square miles of coal, the larger proportion of which is believed to be workable.

DEVELOPMENT AND MINING METHODS.

As previously stated, the period of actual development in the Cumberland Gap coal field extends back a little more than ten years. The Mary Hull mine at Chenoa was opened in November, 1893. The Bryson mine was opened in 1890, and by 1895 there were running the Bryson Mountain, Mingo Nos. 1 and 2 mines, Reliance mine, and the Fork Ridge mine. As near as could be learned, the Bennett Fork mine was opened in 1896, the Excelsior mine in 1898, and the Mary Hull cannel-coal mine was abandoned July 21, 1899. The Ralston mines have been opened up since 1899. Yellow Creek mine was opened January 8, 1902, the Nicholson mine opened in the fall of 1902. During 1903 openings were made at the Mingo No. 1 mine upon the Poplar Lick bed; at the Nicholson mine upon the Klondike bed; above the Fork Ridge mine on Puncheon Camp Branch on the Lower Hignite seam; also on Stony Fork by the Sagamore Coal Company, by Luke and Drummond, and in Coal Branch of Stony Fork by the Ralston Coal Company; also the Turner mine near Middlesboro. In the winter of 1903-4 an opening was also made on Bryson Mountain by the Sterling Coal and Coke Company. The above list gives all the mines upon a commercial scale in this district. Small mines have supplied local needs, and have been opened at a number of points, especially several on the Harlan coal near Harlan. In most cases these small openings have not gone in more than 50 to 75 feet from the outcrop, though a few of them have gone in 200 or 300 feet. Most of the coals of the district are fairly soft, so that a good miner can get out five tons without the use of powder. The common practice in the district is to use 8-foot entries, 60-foot pillars along the main entries, 40-foot pillars along cross entries, and 14- to 15-foot pillars between rooms. Rooms range from 200 to 275 feet in length, at the average width of about 22 feet. An 8-foot neck is driven in 35 feet before turning the room. The larger mines depend mainly upon fans for ventilation, though at an early day furnaces were entirely depended upon. Most of the openings upon the coals are so high above the level of the railroad switch that the coal is sent down to the railroad upon an incline, for which purpose most of the mines use monitors. In some cases the same incline is used for more than one seam.

In regard to the possibilities for future development, at present such development must largely depend on the future extension or construction of railway lines. A new switch was building in 1902-3 up Stony Fork, on which three new mines were being located at the same time. This switch should give access to some of the coal on the north side of Stony Fork and to much of the coal on the south side. Most of the coal in the ridge between Stony Fork and Clear Creek could probably best be reached by a switch on Little Clear Creek, as from that position entries could be driven upon the coal along the center of the syncline, thus securing drainage and easy haulage from both directions. Plans are under way for the construction of a road up Cumberland River as far as Harlan. Should this branch be built, undoubtedly other branches would in a short time follow up the main tributaries, such as Hance, Williams, Toms, Puckett, Forrester, and Wallins creeks, and no doubt within a short time up the three main forks of the Cumberland—Martin, Clover, and Poor. At the present writing the prospect of this road seems favorable, so that when completed practically all of the coal within the area studied should have available transportation facilities. With such facilities it is possible to foresee an almost unlimited future development of this field.

MARKETS AND TRANSPORTATION.

Naturally this coal field will have no competition in supplying any demand within the field or in the part of the Great Valley immediately east along the lines of railroad passing through Cumberland Gap. Within a short distance, however, of Cumberland Gap the coals of this district will come into competition with the coals of the Jellico district and the Big Stone Gap district. In a general way it may be said that this district, in conjunction with the Big Stone Gap district and the Jellico district, will supply the Great Valley through the northern half of Tennessee; in general, through western North Carolina, the northwestern half of South Carolina, and northern Georgia, the three districts mentioned and the coals of the Chattanooga districts will have to compete among themselves, and in this competition for most purposes the coal of this district will probably be able to hold its own.

For domestic purposes the coal of Jellico has already attained an enviable reputation. For the rest of North Carolina and the northeastern part of South Carolina the four fields mentioned will have to compete with the northern Appalachian fields. For a considerable part of the rest of South Carolina and the central part of Georgia these fields will compete with the Birmingham field of Alabama.

The following schedule shows the freight rates to a number of points within the market district already cited. The rates given are for short tons and are from Middlesboro. An additional amount of 50 cents should be added (in case of the present mines) to Middlesboro.

Freight rates from Middlesboro.

	Coal.	Coke.		Coal.	Coke.
Savannah, Ga	$2.05	$2.00	Anderson, Ala	1.40	....
Charleston, S. C	1.90	2.00	Asheville, N. C	2.37	....
Atlanta, Ga	1.40	1.45	Birmingham, Ala	1.40	....
Chattanooga, Tenn	.75	.70	Bristol, Tenn	1.20	....
Sheffield, Ala	1.80	1.25	Macon, Ga	1.85	....
Isabella, Tenn	1.20	1.30	Columbus, Ohio:		
Knoxville, Tenn	.50	.55	Slack and run of mine	.90	....
Athens, Tenn	.80	.90	All other kinds	1.05	....
Columbus, Ga	2.05	2.10	Louisville, Ky	1.10	....
Brunswick, Ga	2.05	2.15	East St. Louis	2.00	....
Cedartown, Ga	1.40	1.45	Mobile, Ala	2.90	....
Anderson, S. C	2.07	....			

MINERAL RESOURCES OTHER THAN COAL.

OIL AND GAS.

On account of the nearness of this field to the recently developed oil fields of Kentucky—Knox and adjacent counties—the question of the presence of oil and gas in this field is one that is frequently brought forward. In several places traces of oil have been found upon the surface of pools along the streams, particularly at low water. Generally the showing was very slight. In one case on Catron Creek, reported after the completion of the field work in 1903, it is said that considerable oil showed. A few wells have been drilled for oil; one of these is in the town of Middlesboro, Ky., and one on Bear Creek in the Log Mountains; other wells have been drilled for water. In all cases these found water, but no oil or gas in any quantity. While it can not be asserted that no oil or gas will be found in this district, a theoretical consideration of the structure of the field leads to a strong doubt of either of those substances ever being obtained there. On account of the upturned position of the rocks in Pine and Cumberland mountains, opportunity has been given theoretically for the escape of the more volatile hydrocarbons, and through the structure within the field, as on Brush Mountain, Rocky Face Mountain, and probably many minor faults scattered through the field which were not seen, due to the stresses and movements to which the rocks here have been subjected, abundant opportunity has been granted the hydrocarbons to escape.

BUILDING STONE.

As is usually the case with Coal Measure sandstones, the sandstones of this district are usually shaly and seldom suitable for building purposes. No sandstones were seen within the limits of the basin proper that suggested the existence of desirable building stones, except on the very flanks of the basin in Pine and Cumberland mountains. Here the sandstones of the Lee formation are upturned, and in places these sandstones are sufficiently pure to make an enduring stone, if stones of suitable color can be found. A small amount of stone was noticed on the trail over Laurel Hill from near the Seven Sisters of Cumberland to a little above Wasiota, and at several places along the mountains these sandstones gave promise of stones suitable for rough structural purposes, with a possibility of some finer gray stone being obtained. On account of the lack of value of the coals in Pine and Cumberland mountains, a very small amount of work was done there, so that we do not feel prepared to indicate the position or extent of the stones there that may prove valuable for building stones, but simply to suggest their presence and the desirability of further exploration in those areas.

SOILS.

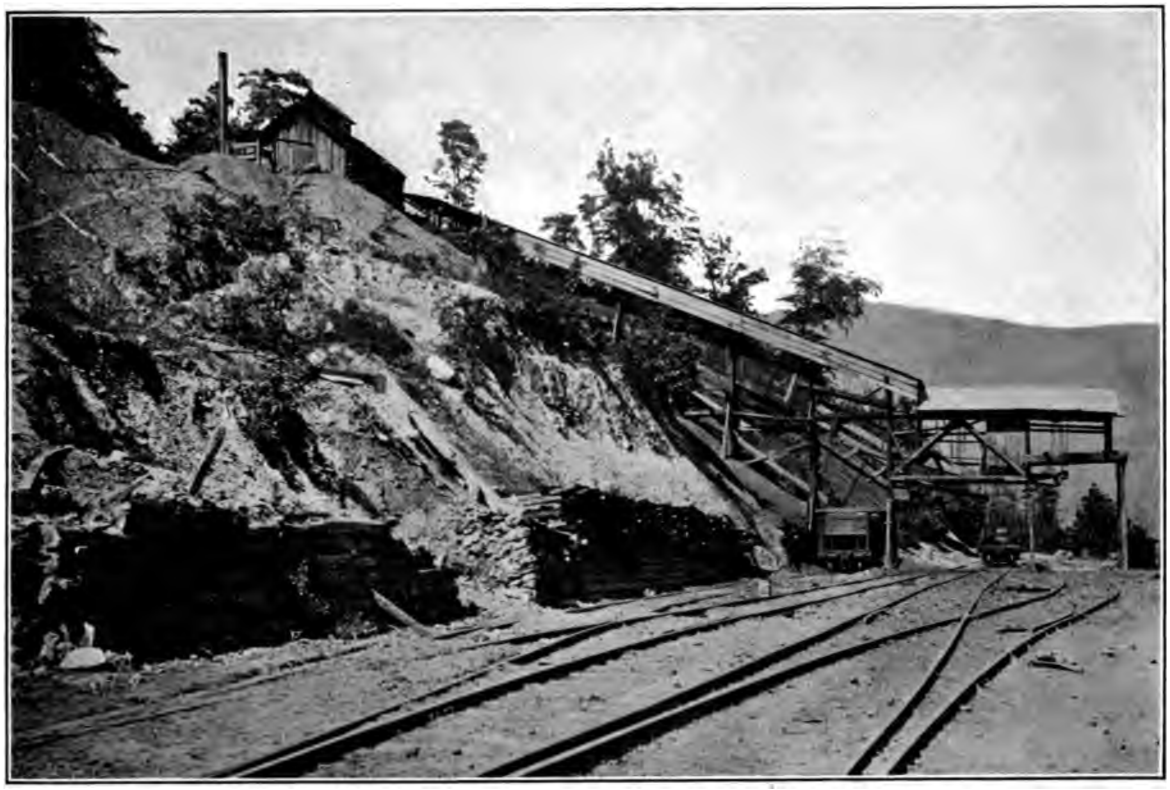
The soils of this region consist of the bottom lands along the Cumberland and its main tributaries, and the soils of the hillsides. The Cumberland Valley soils are fairly productive, considering the lack of limestone in the drainage area from which they are derived. The hillside soils yield largely if properly cultivated, but as they must lie idle every other year and cultivation must be largely by hand, they can not be considered as desirable farming lands. It is a little surprising to find the soil on a hill slope so steep that it can not be plowed yielding from 60 to 80 bushels of corn to the acre, and continue to give a good yield for 20 or 25 years without fertilization if allowed to lie idle every other year.

CLAYS.

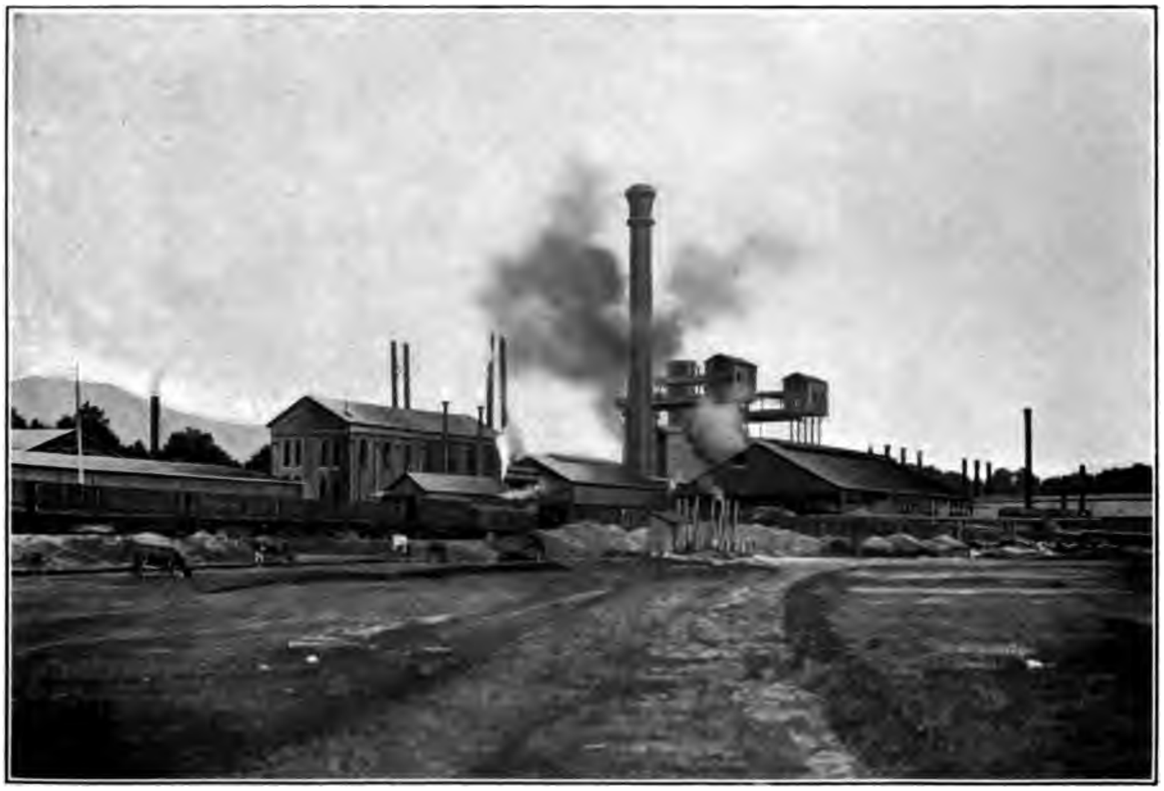
Although at present little considered, the clays of this region may ultimately prove of as much value as the coals. Few shales were noted which appeared suitable for paving brick or similar purposes, the shales usually being sandy, or when containing but a small percentage of silica, being fissile, or bituminous, or otherwise apparently not suitable for the manufacture of the products named. On the other hand, however, the clays found under the coals appear to be of excellent quality, and there is little doubt that in time their use for the manufacture of fire brick and probably for the manufacture of a large variety of clay products will be one of the most valuable assets of this field. In a general way the presence of fire clay, and in many cases its thickness has been noted in connection with the coal. It is probable that special tests will have to be made of the fire clays to determine at what horizons these present the most suitable characteristics for any desired purpose. In 1904 the Middlesboro Pressed Brick Company began the successful manufacture of fire brick, paving brick, and high-grade building brick.

METALLIC MINERALS.

As far as known, no metallic minerals in workable quantities exist in this field. We were shown a specimen of limonite of the Oriskany type, which was reported to come from the headwaters of Shillaly Fork. The whole of that fork was not examined, and it is possible that near the headwaters it has cut through the bottom of the Lee formation, but it hardly seemed probable that it could have cut down to the Oriskany.



A. TIPPLE AT RELIANCE MINE, NEAR MIDDLESBORO.



B. WATT'S IRON FURNACE, MIDDLESBORO.

WATER POWER.

As already stated, the profile of most of the streams of this district is not favorable to the production of water power, though a majority of them have a descent of from 1,000 to 2,000 feet. In most cases the larger share of that descent is close to the heads of the streams, where little volume has been attained. Two exceptions to that rule exist in the headwaters of Martins Fork and Shillaly Fork. On Shillaly Fork there is a fall of about 1,000 feet within a fraction of a mile where the creek turns from the southwestward across to a northward course in running into Clear Fork of Yellow Creek. No estimate was made of the volume of water, but it is certainly enough to furnish probably several hundred horsepower even in a dry season. Martins Fork has a similar fall, but it extends over a much greater distance. In this case it would be necessary to build a high retaining dam, and probably then to carry the water for some distance along the bank until a suitable head had been obtained. Small powers could possibly be obtained from some of the streams on the flanks of Pine Mountain or some of the other streams descending Cumberland Mountain. In most such cases the method of obtaining the power would have to be by the building of high impounding dams near the lower end of the stream courses, selecting some point where the stream has cut through one of the massive cliff-making sandstones. Small water power is now developed at a number of points along Cumberland River and its principal tributaries, and many small mills are to be found scattered in many of the smaller branches of the principal creeks. The power developed in these cases, however, can not be considered of commercial quantity.

TIMBER.

A large share of this area is at present covered with an excellent growth of timber, and much of the surface is probably too steep to be of value for other purposes than raising timber. In the district west of Middlesboro nearly or quite all the first growth of timber has been removed and a good second growth has sprung up. In the district east of Middlesboro the cutting has been selective. The black walnut has practically all been removed, including the stumps. At present the main lumbering is poplar, of which a large quantity and fine growth has existed. At the present rate it will take but a few years to completely exhaust this region of that valuable timber. Near Middlesboro considerable chestnut has been cut for the bark for tanning purposes. Farther to the east there is yet a large amount of fine timber, mainly chestnut and oaks. Trees with diameter of from 3 to 4 and 5 feet are abundant. As before stated, it would seem that a large part of these mountains presents an ideal region for scientific lumbering, the hill slopes being much too steep for practical farming, such farming as is done usually being at the ultimate expense of the soil, for after the exhaustion of the plant and food material in the soil, it is allowed to lie idle in such a way that a large share of it is gullied and washed away before a new growth of timber can be started to hold it in place.

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DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

THE

MONTANA LOBE OF THE KEEWATIN ICE SHEET

BY

FRED. H. H. CALHOUN

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GENERAL FEATURES OF THE AREA.

LOCATION.

The area covered by this investigation lies along the eastern front of the Montana Rockies, between longitude 108° and 113° 40′, and latitude 47° 15′ and 49° 30′. Over the eastern and northern part of this area the ice from the northeast deposited its drift. Over the western part the ice from the Rockies pushed down the mountain valleys and, deploying on the plain, deposited large and well-defined terminal moraines. Extending from the Canadian line to the Missouri there is a strip of country, varying greatly in width, which the ice did not cover.

PROBLEMS PRESENTED.

In studying this region four important subjects present themselves—the eastern drift, the mountain drift, the deposits on the intervening area (which was not glaciated), and the relations of these three surface formations to one another. In order that these relations may be clearly understood the physiography and the general geology of the region must be briefly considered.

PHYSIOGRAPHY.

The region may be divided into three physiographic provinces—the great plains that cover the eastern part of Montana, the foothill belt, and the Rocky Mountains proper. The plains begin at the edge of the foothills and slope eastward with sharp descent. At Midvale, near the base of the mountains, the elevation is 4,788 feet above sea level; at Blackfoot, 20 miles distant, 4,145 feet, giving a slope of 30 feet per mile; at Shelby Junction, 52 miles from Blackfoot, 3,279 feet. The fall between the last-named places is, therefore, 16 feet per mile.

The foothill region separates the plains from the mountains. This confused mass of hills and ridges narrows as it extends southward until, at the mouth of Sun River Canyon, it disappears altogether and the mountain walls rise abruptly from the plains. The height of the foothills averages 1,000 feet, though many individual peaks measure 1,500 feet.

As the foothills are distinct from the plain, so are the mountains distinct from the foothills. Towering above the smaller hills at their base, these mountains raise their nearly vertical faces 4,000 to 5,000 feet above the plain.

The Rocky Mountain divide separates three drainage basins. A drop of water falling near the summit may be carried eastward by the tributaries of the Missouri to the Mississippi and the Gulf of Mexico, northward by St. Mary River or its tributaries into Hudson Bay, or westward by Flathead River into the Pacific. Of these three drainage basins this report is chiefly concerned with the first two. All the streams considered rise on the eastern slope of the Rockies, flow through deep mountain valleys with high, nearly vertical walls, across the foothills in deep, narrow canyons, and finally make their way across the plains in great U-shaped valleys whose forms suggest a long period of erosion.

The region shows at least three periods of erosion, when the land stood at different levels. Running out from the mountains in a general eastward direction are plateaus 900 to 1,000 feet above the present level of the streams. These plateaus out by Willis[a] in the vicinity of Chief Mountain, near the international boundary line, but the same fault appears to extend both northward and southward.[b] It is seen in Sun River and Teton River canyons, though there the Cretaceous appears to lie under a great thickness of limestone, which in this case is not Algonkian but Carboniferous.

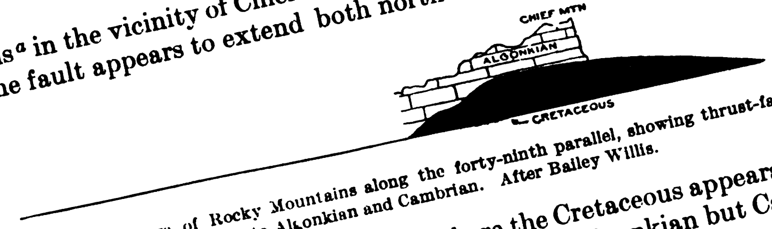

FIG. 2.—Section of frontal range of Rocky Mountains along the forty-ninth parallel, showing thrust-fault relations of Cretaceous to Algonkian and Cambrian. After Bailey Willis.

GENERAL GEOLOGY.

SEDIMENTARY ROCKS.

The rock material forming the mountains is varied. North of Summit Pass the basal member of the series is a hard buff limestone. Above the limestone are argillites, quartzites, and conglomerates. In some places the limestone has been metamorphosed. A fine exposure of the resulting marble is seen on the south side of Rising Wolf. The argillites are red, green, and black, and so hard as to withstand weathering to a remarkable degree. The quartzites are commonly red and white, and are even more durable than the argillites. Some of them contain flat pebbles of argillite, giving to the formations the appearance of a quartzite with interstratified layers of shale. The evidence of their shallow-water origin is seen throughout the series. Ripple marks and sun cracks are found even at the summit of Rising Wolf, nearly 10,000 feet above the sea. Into this great sedimentary series there has been at least one igneous intrusion of diorite. Exposures of this intrusive rock occur in Swiftcurrent Canyon and at several other places on the west slope of the mountains.[c] This rock appears in the drift along the face of the mountain, being abundant in the St. Mary River Valley but gradually decreasing in amount toward the south.

The region lying at the foot of the mountains consists of a high plain sloping abruptly eastward. The beds forming the surface are upper Cretaceous; the lowest member of the system is referred to the Pierre formation of the Montana epoch; the upper member of the system is the Laramie. In the southeastern portion of the area the rocks of the Colorado formation are exposed along Missouri River. This classification of the strata of the region is based wholly on Dawson's classification of the formations to the north. The shales and sandstones of the Pierre formation are exposed at Midvale, in Two Medicine Valley on the Marias near its headwaters, on the Teton, and north of Shelby Junction on the line of the Great Falls and Canada Railroad. There are also outcrops in the disturbed region between the foot of the mountains and the area of horizontal beds.

Near the mountains the Pierre shales become sandy and in places conglomeratic, indicating proximity to an old shore line. The conglomeratic character is well developed in Summit Pass and along the face of the mountains generally. The Fox Hills beds are regarded as deposits of a stage existing between the marine conditions of the Pierre and the fresh-water conditions at the time of the Laramie, and were not identified.

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[a] Willis, Bailey, unpublished manuscript.

[b] Geol. Survey Canada, 1886, vol. 2, Rept. D.

[c] Culver, G. E., Trans. Wis. Acad. Sci., vol. 8, 1891, p 195.

Concretions are found on the surface in great numbers, frequently arranged in belts extending uninterruptedly across the country (Pl. II, *A*).

These concretions are often found in the drift.

IGNEOUS ROCKS.

The continuity of the sedimentary series of the plain is interrupted by igneous outcrops in various parts of the region studied. Chief among these are the Sweetgrass Hills, igneous intrusions south of Sun River on the headwaters of the Muddy, the Highwoods, the Bearpaws, the Little Rocky Mountains, and the Larb Hills.

The Sweetgrass Hills afford data for the solution of some of the glacial problems of the region, and therefore deserve especial mention. These hills or buttes are usually spoken of as outliers of the Montana Rockies, but they are not such in any proper sense of the term. The Rockies were formed by a series of faults, while the Sweetgrass Hills are the result of igneous intrusions, which lifted the sedimentary layers and left them dipping at high angles from the central igneous core. The hills are three in number, known as East, Middle, and West buttes. Of these, West Butte is the highest, its summit being about 6,800 feet (aneroid) above sea level. The East Butte is several hundred feet lower, while Middle Butte, the smallest of the three, is but 6,000 feet in height.

The igneous intrusions which formed these buttes may have belonged to the mountain-making period at the end of the Mesozoic, as volcanic activity was at this time great, or may be still younger. Gold, silver, and copper are found to some extent in the buttes, occurring in veins, usually along the contact between the sedimentary series and the intrusive mass.

The area of igneous rock found south of Sun River is some 30 miles from the base of the mountains. It caps some of the high buttes between Sun and Missouri rivers. The easternmost outlier is found at Square Butte, in T. 20, R. 2 W. The rock is pyroxene-porphyry, rather dense and roughly columnar. It rests on a sandstone formation, which contains oyster shells and fine examples of the straight baculite shell. These fossils lie within a few inches of the contact and are perfectly preserved. The sandstone shows scarcely a sign of metamorphism, even at the zone of contact. The lava flowed over a very uneven surface. On Square Butte the contact is 400 feet above the level of the plain; on Crown Butte the bottom of the porphyry is but 100 feet above the plain.

The Highwood Mountains are the result of former extensive volcanic action. Early in the Eocene a great igneous mass pushed its way through the sedimentary layers to an unknown height above the plain. At the present time the mountains are much subdued by erosion and weathering, a number of peaks have been formed, and great buttes have been separated from the main mass of the flow. The mountains and the plains surrounding them have been cut by dikes, which radiate in all directions.[a]

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[a] Weed, W. H., Description of the Fort Benton district: Geologic Atlas U. S., folio 55, U. S. Geol. Survey, 1899.

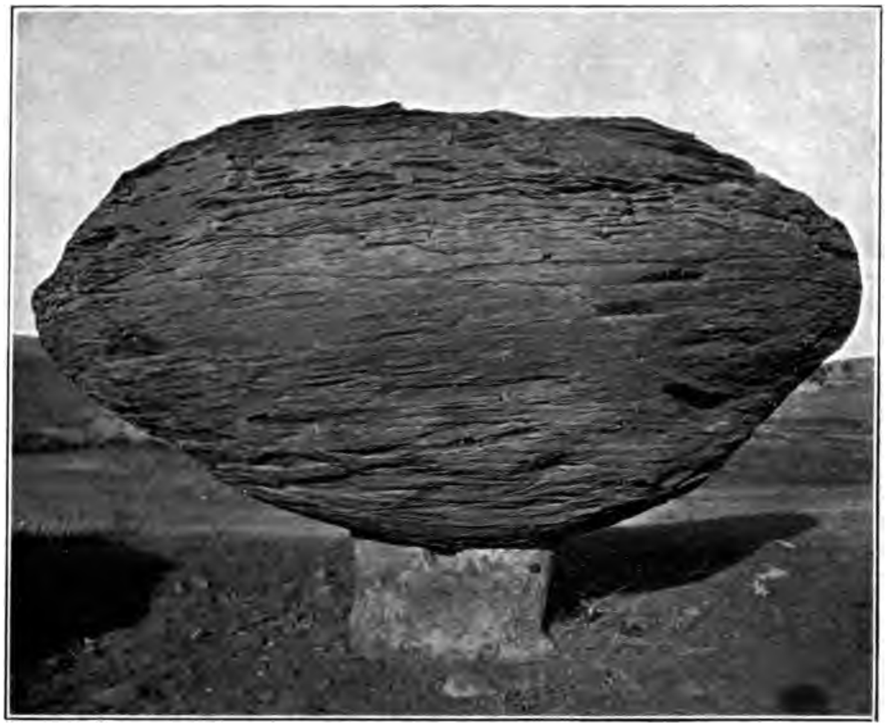
Just north of the Highwood Mountains lies a very peculiar valley, locally known as the Sag (Pl. II, *B*), which extends from Highwood Creek Valley on the west to Arrow River Valley on the east. The Sag is 80 miles long and in many places is very wide and deep. Near Steele it is over a mile wide, with valley walls 600 to 800 feet high. Its great size and peculiar course have led some geologists to consider it a pre-Glacial channel of the Missouri, but its close association with the ice edge suggests another interpretation, which will be discussed later.

Directly northeast of Highwood Peak, the highest point of the Highwoods, and at a distance of some 70 miles, the Bearpaw Mountains rise above the plain. Like the Highwoods, these mountains are volcanic, being composed of lava flows resembling those which formed the Highwoods. Dike rock is less common, and as a whole the Bearpaws are older, being past their maturity. The range is made up of low rounded peaks separated from one another by wide fertile valleys. The two ranges are connected by a system of dikes, but it seems evident from the topography that if volcanic activity began at the same geologic period, the Highwood center continued active long after flow in the Bearpaw group had ceased.

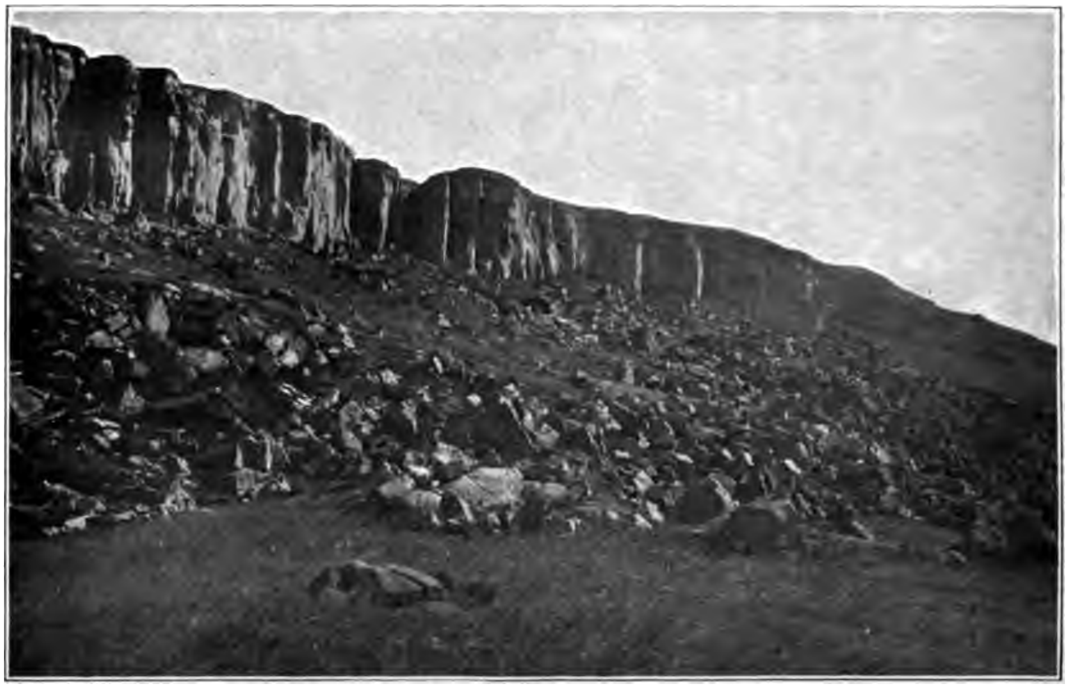
The Little Rockies, the most picturesque and interesting of the three mountain groups, are situated some 50 miles southeast of the Bearpaws. In contrast to the Bearpaws these mountains appear young. Mission Peak, the highest, stands 3,000 feet above the level of the plain. The valleys are narrow and canyons are not infrequent. The canyon through which the St. Paul's Mission–Landusky road passes is 5 miles long and often 500 feet deep. The central mass of the mountains is of porphyry, which is surrounded on all sides by limestone of Carboniferous age. Cretaceous sandstone lies on the limestone and extends outside the limestone area, dipping away from it at a low angle. The porphyry and the limestone are cut by dikes of gneiss and schist. None of these dikes were observed to extend into the sandstone, but some doubtless intersect it also. The gneisses and schists are of many varieties and are not found in the other mountain groups. In the porphyry are pockets of crystalline limestone and quartzite, which appear to be part of the sedimentary series, inclosed in some way by the igneous mass. In places near the porphyry shaly parts of the limestone have been turned to phyllite.

The metamorphic rocks that occur in the mountain group have been carried out by streams and deposited along their channels and on their flood plains. These rocks are in no wise different from some of the bowlders of the Keewatin drift and occur in the same area. Where all morainic topography has been destroyed by erosion, and where that topography was never developed, the tracing of the former extent of the ice becomes a complex and difficult problem.

The Larb Hills seem to be the top of a dome through which the streams have eroded great valleys but have not yet cut sufficiently deep to reach the igneous center. These hills lie east of the Little Rockies and form the breaks of the Missouri. The highest point is some 3,500 feet above sea level and 1,200 feet above the level of the plain. Between these mountain groups lie broad plains, which had a marked influence on the edge of the ice.



A. PERCHED CONCRETION WEATHERED FROM CRETACEOUS SANDSTONE.



B. THE SHONKIN SAG.

The sag at this point is about 600 feet deep.

SURFACE FORMATIONS.

QUARTZITE GRAVELS.

CHARACTER.

On the plateaus between the streams, on the terraces and slopes in the stream valleys, and in the present channels of the watercourses are found the surface formations with which this report deals. There are four such surface formations: (1) A gravel deposit, found in the driftless area; (2) morainic material brought in by the ice from the mountains; (3) morainic material deposited by the ice from the northeast; and (4) the present fluvial deposits. The last are of so little importance that they need not be considered.

Between the moraines deposited by the Keewatin ice sheet and the valley glaciers and on the surface of the strip of nonglaciated country lies a peculiar formation which will be spoken of as the quartzite gravels. These gravels are made up of argillite and quartzite formations of the mountains. Limestone is rarely present. The few fragments found show the result of long-continued weathering. In some cases all the calcium carbonate has disappeared, leaving nothing but irregular masses of chert. In general the quartzite and argillite pebbles making up the formation are well rounded, though some still show traces of angularity. The fact that these hard quartzites are generally smooth and round, taken together with the absence of any appreciable quantity of limestone or other nonresistant rock, shows conclusively that the constituents of the gravel were subjected to prolonged wear. In size the pebbles are rather uniform, being on the average 3 or 4 inches in diameter. Isolated specimens found near the mountains measure as much as 12 inches in diameter.

South of the forty-ninth parallel the character of the gravels changes with the character of the rocks forming the front of the mountains. South of Birch Creek the quartzites and argillites are less common. South of the Teton Ridge the gravels consist of small cherty pebbles, the residual material of the original cherty limestones.

DISTRIBUTION.

How far eastward the gravel extends is not known. East of latitude 112° the formation is buried by drift beds. Beneath the drift the gravels have been found on the Milk, Marias, Teton, and Missouri rivers. Dawson describes them as found 200 to 500 miles east of the mountains. They appear in the drift of the Keewatin ice sheet and make up a considerable per cent of its rock material. Their topographic positions are significant. The high divides between the watercourses are capped by them to a depth of from 1 to 10 feet, but they are absent from the divides near the mountains and from some of the high buttes south of Sun River, which, lava-capped and standing 1,000 feet above the plains, are covered only by the residual material from the lava itself. The gravels appear on the slopes descending from the higher to lower levels and for the most part covering them. On the flats adjacent to the present streams they are sometimes absent, and isolated areas in front of the moraine deposited by the Keewatin ice sheet are not covered by them. Taking the entire area into consideration, the gravels are very persistent. Their relation to the other surface formations, their origin, and their age will be considered later.

DRIFT OF THE MOUNTAIN ICE.

DISTRIBUTION OF THE MOUNTAIN GLACIERS.

In the distribution of glaciers, living and extinct, in the western mountains, one feature which stands out above all others is their greater extent on the western slopes. In the Sierra Nevada in Glacial time the western slope was one continuous ice sheet,[a] while on the eastern side of the range the glaciation was confined to a few narrow gorges. In Colorado the heaviest glaciation was on the west side of the mountain ranges; the La Plata Mountains, which are the first to catch the moist winds from the Pacific, were heavily glaciated on the west side; in the San Juan Mountains there was not only a much greater thickness of ice on the west slope, but the territory covered by the ice was much larger.[b] In Washington the western sides of the ranges suffered severe glaciation, and the Wasatch Mountains were more heavily glaciated on the west than on the east.

The reason for this is evident. The prevailing winds over the western mountains were from the west and carried with them moisture gathered from the Pacific. This in part was deposited on the first mountain slope, because here the currents were forced to ascend and therefore precipitated their moisture. The larger part of what was carried over was deposited, not on the eastern slope of the same range, where the air currents were descending and where instead of precipitation there would be, to some extent, drying winds, but on the western side of the next. Glaciation in the mountains of Montana should follow the same law, and the western slope should be more heavily glaciated than the east. During the work in the field evidence was found to show that practically all the mountain valleys between the Waterton and the Missouri on the east side of the range were once filled with glacial ice. The western slope, though not studied in detail, appears to have been more nearly covered. Large glaciers occupied South and Middle forks of Flathead River, and into these main valleys there flowed small ice tributaries from the sides. Into the valley now occupied by Flathead Lake these ice streams poured and united to form a great piedmont glacier.[c] This glacier was augmented by an ice lobe coming from the north, for striations have been found running north and south on the west side of the Kootenai Mountains and on the low mountains north of Kalispel. The moraines along the southern edge of Flathead Lake appear to have been deposited by the piedmont glacier thus formed.[d] Whether the lobe from the north was a part of the Cordilleran ice sheet or a great glacier formed in the valley north of Kalispel is yet to be determined.

The main divide of the Rockies formed the collecting ground for the glaciers. Those which made their way down the west side were of great extent, and in some cases covered the ridges between the streams. Those on the east slope were confined to the mountain valleys, and appear to have had no connection with each other until the separate glaciers reached the plain and, deploying, united to form a piedmont glacier extending along the foot of the range. During Glacial time all the great valleys and many of the minor ones in the area studied contained glaciers. From 14 mountain valleys the ice reached beyond the mouth of the canyon and deployed upon the plains. In other valleys the ice did not reach the plain, but deposited its moraines across the canyon somewhere above the point of debouchure.

---

[a] Kneeland, Samuel, Glaciers of the Yosemite Valley: Proc. Boston Soc. Nat. Hist., vol. 15, p. 37.

[b] Stone, George H., Glacial gravels of Maine: Mon. U. S. Geol. Survey, vol. 34, 1899, pp. 338–355.

[c] Garrey, George, unpublished manuscript.

[d] Chamberlin, T. C.: Seventh Ann. Rept. U. S. Geol. Survey, 1888, p. 78.

DETAILED DESCRIPTIONS OF THE MOUNTAIN GLACIERS.

Sun River Glacier.—The area comprised in the Sun River system is that which lies between Dearborn River on the south, Missouri River on the east, and Teton River on the north. For the first 50 miles of its course North Fork of Sun River (the main branch) flows nearly due south, parallel to the main divide of the Rockies. It receives numerous tributaries from the west which have their heads at the very top of the divide. The course of the river abruptly changes in T. 22, R. 9 W., whence it flows eastward through a deep, narrow canyon in the mountains and, emerging on the plain, continues in the same direction to its junction with the Missouri, 75 miles distant.

The glacier which occupied the valley of Sun River was the largest one south of Summit Pass. At the present time Sun River drains a considerable area of mountain territory, and in the past it was well situated for collecting the glaciers which made their way down the eastern slope through its tributary valleys. For a distance of 50 miles Sun River received those tributary ice tongues which, had the drainage been to the east, would have been carried in independent valleys directly to the plains. The result of this concentration of the ice into one valley was a glacier of considerable size. .

The mouth of Sun River Canyon is narrow, but it was through this restricted opening that the ice pushed, tearing great blocks from the sides, cutting deep grooves in the valley walls, and smoothing and polishing the rock to a greater extent than in any other canyon along this part of the range. (Pl. III, *B*.)

The sides of the canyon are glaciated to a height of over 1,600 feet, the change from the glaciated to the nonglaciated surface being easily made out by the rather abrupt change in the topography. From the upper limit of glaciation at the mouth of the canyon to the terminal moraine, a distance of 18 miles, the fall of the upper surface of the ice was about 2,200 feet, giving an average decline of about 130 feet per mile. This glacier at its maximum extent reached to a point northeast of Augusta, where its moraine now crosses Sun River in a north-south direction. On the south side of the river and about 1 mile from it, the moraine turns S. 70° W. and continues in that direction for some distance. Beyond this the moraine on this side of the river was not traced, but it probably joins that deposited by the glacier which occupied South Fork of Sun River.

On the north side of Sun River the ice pushed eastward on the south side of a high ridge which forms the divide between Sun River and Deep Creek. For a distance of about 3 miles the moraine lies along the south side of this ridge, but at a point 3 miles north of Willow Creek it reaches the top of the ridge and swings to the north. Near the mountains the moraine of the Sun River Glacier joins that of the Deep Creek Glacier.

The outer moraine of the Sun River Glacier is well marked. In places it is about one-half mile wide and bears many basins which contain water in spring but are dry in summer. This moraine, in sharp contrast to those farther north, is strewn with great numbers of large limestone bowlders, the largest noted being 18 by 12 by 12 feet. Part of this bowlder is buried and the numerous large fragments scattered around its base show that it was once much larger.

Three miles west of the outer moraine there is a well-marked recessional moraine. A second recessional moraine is found just west of Willow Creek. This is not so well defined as the first, though it is of sufficient size to indicate that the ice front remained stationary here for a considerable period of time. The topography of these two recessional moraines is not so characteristic as that of the terminal ridge. There are no well-defined basins, and the bowlders are not so large nor so numerous. The third recessional moraine is of a very different type. It is marked by a series of sharp ridges inclosing lake basins. The bowlders are again numerous and large, and bear marks of severe glaciation, some of them showing grooves 3 feet across. The bowlders in this recessional moraine appear to have suffered considerably less from weathering than those in the outer moraines. As will be pointed out later, this same difference in the character of the recessional moraines is found in other valleys, and it is possible that this better-developed moraine is the result of a rather distinct ice stage.

Between the third recessional moraine and the mountains there is an extensive lake flat, now drained by Willow Creek. Over this old lake bed are scattered a number of alkali lakelets, in which so much alkaline deposition has taken place that, at a distance, they look like ice surfaces.

The bowlders deposited by the Sun River Glacier are chiefly of limestone. Sandstone of all varieties and colors, a peculiar flinty rock, and both red and black slates are also found. Besides these sedimentary rocks there are several varieties of diorite.

At the mouth of Sun River Canyon there is no rock but limestone exposed. The sandstone, slate, and diorite must have been derived from the upper portion of the river basin. The valley trains reached at least to the town of Sun River, where the river runs onto a plain with a fall of but 2½ feet per mile. Because of the sudden check in the velocity of the stream, the gravels, if they extend farther, are covered by later fluvial deposits.

Deep Creek Glacier.—Deep Creek, one of the most important branches of Teton River, issues from the mountains through a very narrow canyon. This stream does not extend far back into the mountains, and the area at the head of the creek was too small to gather any great accumulation of snow during Glacial time. The north and south course of Sun River for so many miles enables it to gather most of the precipitation on the east side of the divide. In Glacial time the same was true. Most of the ice which gathered along the present valley of Sun River was tributary to the glacier which formed in that valley, and little got into the streams to the north. For this reason the Deep Creek Glacier was small and moved but a short distance out from the foot of the mountains, its terminal moraine being found in sec. 32, T. 23, R. 8 W. The local character of the drift is evident from the absence of diorite, quartzite, and sandstone bowlders, showing that the glacier could have moved only over limestone rocks and could not have extended far back into the mountains. The ice which issued from the mountains appears to have been confined entirely to South Fork of Deep Creek, for the valley of North Fork is not glaciated. The moraine from South Fork does not cross North Fork, though at some places it lies so near it as to suggest that the ice filled the old channel and pushed the stream to the north. South of Deep Creek the ice was continuous with that of the Sun River Glacier, but to the north the plain at the base of the mountains is not glaciated for a distance of 8 miles. In this direction the mountains rise abruptly from the plain, and there is no opening through which a glacier could have come till Teton River is reached.

Teton River Glacier.—Two streams but half a mile apart issue from deep, narrow gaps in the mountains, and, joining a mile or two below the mouth of the canyon, form Teton River. Like Sun River the course of the Teton in the mountains is north and south, and though much of the ice which collected near its headwaters was diverted into the Sun River basin, enough was left to form two good-sized glaciers. The ice issuing from these narrow passes immediately joined and deployed upon an unusually flat plain. The glacier thus formed, though extending but a few miles east of the mountains, gives evidence of having been very powerful and active. The terminal moraine on the north side of the river consists of a series of sharp ridges, which form a belt over a mile wide. They are so steep and are covered with so many limestone bowlders that the moraine is difficult to cross on horseback. The terminal moraine is covered with a growth of stunted pine trees, which are found neither on the ground moraine nor on the plain to the east. The north and south edges of the ice formed two moraines which extend parallel to each other for a distance of 6 miles from the mouth of the canyon. They are about 3 miles apart and are well developed throughout their entire extent. This development of the moraines along the side of the glacier is in sharp contrast to that formed at the end of the ice. There the moraine is low and of weak relief. Either the ice did not form a strong terminal moraine or the river has since eroded a considerable portion of it. The amount of ice coming from the north gap was greater than that which came from the south one. This is shown by the great amount of ice erosion in the north valley, the higher level to which the canyon walls were glaciated, and by the fact that the ice spread north from the mouth of the canyon of North Fork for a greater distance than it spread south of South Fork. The bowlders of the Teton Glacier till sheet consist of limestones and sandstones, no diorite being found.

Muddy Creek glaciers.—Muddy Creek is formed by the union of many small streams, but two of which issue from the mountains. Most of the tributaries have their source in springs on the sides of the mountains and are intermittent, contributing to the main stream only while the mountain snows are melting. The two main branches issue from what are known as Black Leaf and Muddy canyons. Of these, Black Leaf Canyon lies to the south and contained a glacier which extended somewhat more than a mile beyond the mouth of the canyon. The material making up the moraine of this glacier is a heavy bowlder clay, containing many limestone bowlders and few of sandstone. The moraine, which reaches a height of 200 feet and has the form of a sharp ridge, is the highest seen in this region. The glacier from Black Leaf Canyon was not connected with any other glacier either north or south. The canyon of the Muddy also contained a glacier which pushed out on the plain a mile from the mouth of the canyon, and resembled in many ways the glacier which issued from Black Leaf Valley.

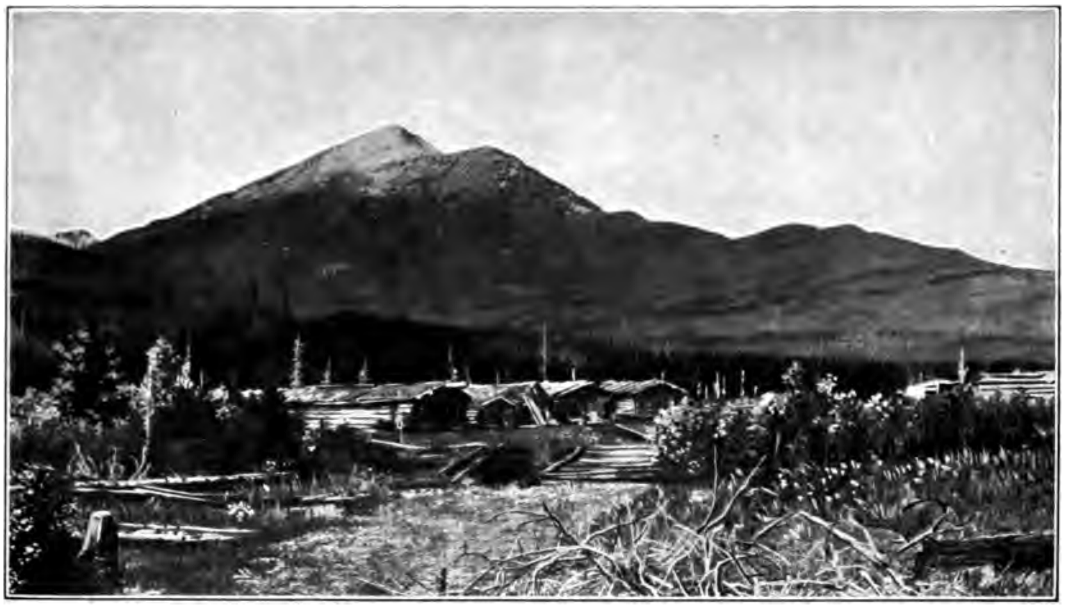
Dupuyer Creek Glacier.—The next glaciated canyon to the north is the one now occupied by Dupuyer Creek. This stream heads in the mountains just north of the sources of Teton and Sun rivers and contained a glacier which extended 3 miles eastward from the mouth of the canyon and formed a well-defined moraine, dotted with many small lakes and ponds. Lakes in the moraines south of Dupuyer Creek are common. Bowlders, which are numerous in the till of the other moraines, are not abundant here. The height to which the ice reached is shown on the surface of the canyon walls, and from these we may determine its slope. At the mouth of the canyon the walls are glaciated to a height of about 1,000 feet. Beyond the canyon for the first three-fourths mile the decline of the ice as shown by the slope of the moraine was 750 feet; in the next 2¼ miles to the terminal moraine it was but 450 feet, making 1,200 feet for the 3 miles, or an average of 400 feet per mile. As soon as the ice left the confines of the canyon it deployed rapidly.

Sheep Canyon Glacier.—There was a small glacier in Sheep Canyon, but its moraines show no striking peculiarities.

Blackfoot Glacier.—Properly speaking, the Blackfoot Glacier consisted of a group of glaciers which, reaching the plain, joined and spread to the east. At least 5 such ice lobes were concerned in the formation of a large piedmont glacier which extended about 50 miles from the main divide, and which, in its widest part, was over 30 miles across.

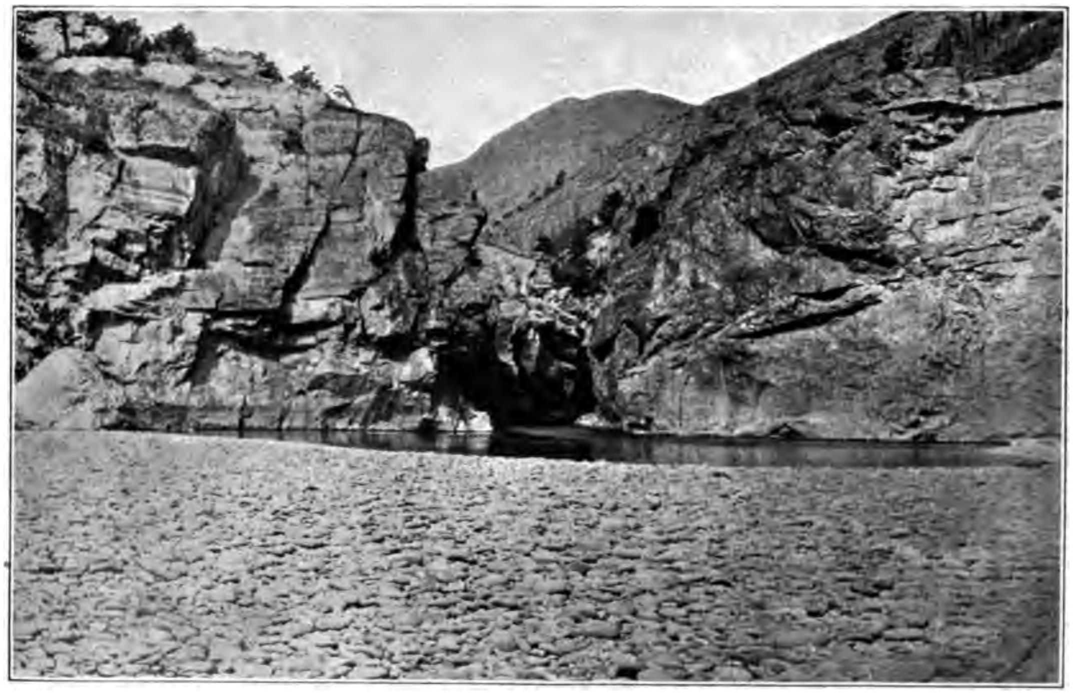
The main collecting ground for the snow which furnished the ice was in the low pass now crossed by the Great Northern Railway. (Pl. III, *A*.) From this pass the ice moved both eastward and westward. The center of accumulation may have been west of the top of the pass, for the rocks for nearly 2,000 feet above Summit station are smoothed and polished, and well-marked glacial bowlders are found at a height of 1,000 feet above the 5,205-foot bench mark at the summit. Along the side of the mountains north of the track and east of Summit station there is a terrace 1,800 feet above the valley level, which seems to coincide with the upper limit of glaciation and to represent the thickness of the ice near the point of origin. Thence the front of the ice descended to an altitude of 3,800 feet. This would give a slope to the surface of 65 feet per mile, a low slope for a mountain glacier.

The southernmost glacier that was tributary to the Blackfoot Glacier came from the valley of Birch Creek. It extended southward as far as the divide between Birch and Sheep creeks, but in no place did it meet the ice which issued from Dupuyer Creek Canyon. The eastern edge of the ice swung across the river due north and south at a point in sec. 30, T. 29, R. 8 W., but on the flat on each side of the river the ice front curved to the west. North of Birch Creek is a high ridge, which forms the divide between that stream and Blacktail Creek so high as to prevent the ice of the piedmont glacier from extending far into the narrow Blacktail Valley. The bowlders in the Birch Creek drift are for the most part limestone, the most common variety being a dull noncrystalline limestone. A light-colored crystalline type and a cherty variety are also common. There are sandstone bowlders, but they are not abundant. The glacier in Birch Creek Valley formed several recessional moraines, but they are not so sharply defined as those in the valleys farther south.



A. SUMMIT PASS AND ADJACENT VALLEYS.

The main valley was completely filled with glacial ice. The one at the left contained a glacier tributary to the main stream.



B. SUN RIVER CANYON.

This photograph shows the glaciated surfaces in the background and the amount of post-Glacial cutting.

The valleys of Blacktail and Whitetail creeks furnished great glaciers to the ice mass at the foot of the mountains, causing a bulge in the ice front, which carried the edge of the ice nearly to Fourhorn Lake. The moraine deposited was of the same character as that in Birch Creek Valley, and contains the same sorts of rock. Within the moraine of the Blacktail Glacier the country is rolling, and there are a few shallow lakes, the topography being essentially that of a ground moraine. The bowlders south of Badger Creek consist of dull-colored limestones and sandstones of the same character as those found in the till of each valley glacier north of Sun River.

North of Badger Creek, near the Little Badger, the character of the drift suddenly changes. The dull rocks give place to the red, green, white, black, and mottled quartzites and argillites that are characteristic of the drift from this point north. Diorites and a peculiar conglomerate also appear. This conglomerate is formed of siliceous material, varying in size from pebbles an inch in diameter to the finest grains, the entire mass being cemented by silica and hard as quartzite. The limit of the two sorts of bowlders is marked approximately by the line where the ice from Badger Creek and the valleys south of it joined the ice which issued from Summit Pass.

The influence of the Two Medicine Glacier upon the confluent piedmont glacier is seen by the great extension of the ice to the east in this latitude. The terminal moraine of the piedmont glacier just west of Fourhorn Lake suddenly swings to the east and crosses the Piegan-Robare trail about 4 miles south of the Old Stockade. Here its direction is N. 40° E, and its edge lies along the foot of a cliff about 250 feet high. In some places the ice carried its moraine to within a hundred yards of the foot of the plateau. In Glacial time the drainage may have lain between the moraine and the cliff, where it formed coulees, which left small valley trains beyond the edge of the ice. These coulees appear to have contained but little water since the ice left. The moraine extending from this point northeastward is sharply defined. Shallow basins, which are filled with water in spring and dry in late summer, dot its surface at frequent intervals. The country is very rough, and the hummocky topography is common. The surface slopes abruptly toward Two Medicine River, but post-Glacial erosion has made but little headway. The moraine crosses Two Medicine River 8 miles west of the point where that stream joins the Marias, and 5 miles east of its junction with the Badger. On the north side of the river the moraine is finely developed. Lakes are numerous, fine outwash plains are common, and valley trains occur at many places along the front of the moraine. The valley train of Two Medicine Valley is now covered by later deposits.

Within the terminal moraine several recessional moraines are found, one of which lies just east of Kipp. A second forms the site of the village of Browning. Between Browning and Kipp there is a flat plain, which at one time was covered by a lake, which persisted until Willow Creek cut through the terminal moraine at Carlow and drained it. The third recessional moraine is found near the mountains on the plain just east of the North Fork of Two Medicine River. This moraine appears to be much younger than the moraines at Browning and Kipp. The lakes in it are so numerous and so close together and the topography is so sharply defined that it is a trying undertaking to cross it. There has been little erosion of the drift.

though the moraine is on a slope, and the average rainfall 30 inches. This moraine corresponds with the better-developed recessional ridge found in Sun River Valley. There are other recessional moraines in the valleys of North and South forks of Two Medicine River. Lower and middle Two Medicine lakes were formed by the deposition of a ridge or ridges of till across the valley, while the upper lake basin was formed by the gouging out of the rock by the ice and by deposition.

The ice in the vicinity of lower Two Medicine Lake was somewhat over 1,500 feet thick. Along South Fork of Two Medicine Valley there are also several recessional moraines. One well-defined ridge with lakes and kettles occurs 7 miles east of Summit station, while another, not so well defined, is found at Summit.

The ice which filled the valleys of the various branches of the Two Medicine River formed the northern part of the piedmont glacier. The northern edge of the ice lay along the south bank of Cutbank Creek from the junction of the two forks to a point north of Blackfoot. The relation existing between the streams and the moraine is such as to suggest a considerable change in drainage.

Cutbank Creek Glacier.—North of the great glacier just described the ice from the valleys of the North and South forks of Cutbank Creek joined and pushed eastward as far as the junction of the two streams. The outer moraine is well marked, and is about three-fourths of a mile wide. On ascending the valley of the North Fork, which is the larger of the two tributaries, four recessional moraines are crossed. There is no appreciable difference in the appearance of these moraines, though some of those found within the outer moraine are better developed than the outermost ridge itself.

Between the two outer moraines are drumloidal hills, small but perfectly formed. Esker-like ridges were seen in a number of places, but in no case was a ridge over 100 yards in length found. Several of the recessional moraines in this valley show themselves as terraces on the sides of the bluffs, and as spurs from these terraces. The moraine between the spurs, if ever continuous, appears to have been removed by erosion. The valley floor back of the last complete recessional moraine is composed of stratified gravels, in places 40 feet deep. There was not only a great amount of water associated with the glacier, but it was concentrated into a comparatively narrow channel. A gravel train extends for miles down the valley east of the outermost moraine.

The ice which came down North Fork of Cutbank Creek completely filled the valley, though this, at the mouth of the canyon, is more than 1,200 feet deep, but did not spread over the plateau to the north. To the south the ice partly covered the ridge between the North and South forks of Cutbank Creek. The slope of the ice from the mouth of the canyon to the terminal moraine was about 200 feet per mile.

Milk River Glacier.—The valley of South Fork of Milk River contained a glacier which was developed in Cutbank Valley and not in Milk Valley itself. South Fork of Milk River heads back on the slopes of Wolf Calf Mountain, and has cut but a very small valley, far too small to give rise to a glacier of such proportions as those of the glacier which deposited moraines along Milk River east as far as Antelope ranch. The divide which extends between the headwaters of North Fork of Cutbank Creek and South Fork of Milk River contains a depression through which the ice from the former valley spread into the latter. The moraine formed by this lobe is well defined and extends about 4 miles down the valley.

The country between the Milk River lobe and Milk River Ridge, a notable eminence that runs in a northerly direction from Divide Mountain, is not glaciated. This ridge, which, near the mountains, is more than 1,500 feet high, prevented the ice occupying St. Mary Valley from flowing directly east and diverted it to the north. At the foot of the lower St. Mary Lake the ridge becomes lower and the ice from the St. Mary Valley, crossing it, spread to the east in the valley now occupied by Duck Lake. The area between Duck Lake and South Fork of Milk River is the largest driftless area along the face of the mountains between the forty-ninth parallel and Sun River.

St. Mary River Glacier.—A glacier of great size occupied the valley of St. Mary River and extended northward over the Canadian plains for an unknown distance. The valley of the St. Mary is somewhat typical of the glacial valleys along the east face of the Rockies and for that reason will be described in detail, the data concerning it having been collected for the most part by Mr. Bruce McLeish.

St. Mary River rises at the very foot of the main divide of the Rockies, and after flowing eastward through a most picturesque valley suddenly bends to the north and crosses the forty-ninth parallel in longitude 113° 20′. In two places in its course the river widens into lakes of great beauty. The lower St. Mary Lake is about 7 miles in length, the upper about 10 miles. Both lakes are narrow, neither exceeding 1½ miles in width. St. Mary River below the lakes is a wide, shallow, rapid stream, which carries in the course of a year an immense volume of water.

At the present time there are a number of glaciers found at the headwaters of St. Mary River and its tributaries. Some of them, such as the Blackfoot and the Grinnell glaciers, are several square miles in extent. These glaciers may be the last remnants of a great ice mass which formerly filled the basin of the St. Mary River. In following this stream to its source many recessional moraines are found, deposited as the ice retreated up the valley. The last moraines are those now forming at the very edge of the glaciers. Some 60 miles intervene between the accumulations of material at the edge of the ice and those deposited when the glacier had its greatest known extension to the northward. The numerous recessional moraines show plainly where the ice rallied in the unequal contest with adverse climatic conditions. The different stages in the retreat are also indicated by a dozen or more terraces which rise in succession on the western slope of Milk River Ridge to a height of 1,000 feet. It was suggested by Culver[a] that these terraces were the result of lake action; but as they slope sharply to the east at about the angle that the surface of the ice should have maintained they are clearly not the work of lake water. The numerous lakes, the sharp ridges, and the great number of bowlders that occur on these terraces indicate glacial action and they fall into the class of morainal terraces. As these terraces are traced eastward it is found that they develop below Duck Lake into terminal and recessional moraines. The ice below Duck Lake turned westward and again crossed Milk River Ridge in a north-south direction and spread east and west in St. Mary River Valley. The outer moraine was deposited as a terrace on the north slope of the ridge. This terrace descended 1,200 feet in 4 miles, giving the ice an average slope of 300 feet per mile in this valley.

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[a] Trans. Wis. Acad. Sci., vol. 8, 1891.

The St. Mary Glacier proper received a number of large tributary ice streams, the largest of which was formed in Swiftcurrent Valley and was but little inferior in size to the St. Mary Glacier. Its thickness where it joined the main ice mass must have been over 1,300 feet. Both the north and south forks of Kennedy Creek contained glaciers, which, however, were smaller than those found in the other valleys. That they were local is shown by the great abundance of limestone bowlders in the drift they deposited and the absence of any other variety of rock. The region occupied by these glaciers was surrounded by the Algonkian limestone.

The valleys of Waterton and Belly rivers and of Lees Creek were also glaciated. Whether the tongues of ice from these valleys joined one another north of the boundary line and formed a piedmont glacier similar to that south of the forty-ninth parallel has not been determined, but from their size such a conclusion seems tenable.

DRIFT OF THE KEEWATIN ICE SHEET.

TERMINAL MORAINE.

During the Glacial period as many as five ice sheets, it is believed, covered the northern part of the United States. The bodies of drift deposited by the successive ice sheets have never been found one above another in a single locailty, but from their interrelations the following order of deposition has been established: (1) Sub-Aftonian, (2) Kansan, (3) Illinoian, (4) Iowan, (5) Wisconsin. Between these drift sheets interglacial deposits occur which indicate modifications of the climate, sometimes very important, between the successive advances of the ice.

In the region just north of the area under consideration Dawson found three drift sheets. The earliest he named the Albertan. The drift sheet resting on the Albertan is correlated with the Kansan and the upper bowlder clay with the Iowan. Between the two upper drift sheets are interglacial deposits which are best developed along Belly River. This classification of Dawson's[a] was merely tentative, and it is a question whether it can be held. The following detailed description of the terminal moraine and the subsequent discussion of the relations of the Keewatin drift to the drift deposited by the mountain glaciers in the various river valleys will throw some light on the age of the various drift sheets found in this region.

During the season of 1901 the moraine of the northeastern ice sheet was traced from the Missouri below Great Falls westward to Choteau, and thence northward to the international boundary line in longitude 112° 20′. From this point it bends westward until it reaches Waterton River, where it turns to the north, following a course nearly parallel to the mountains.[b] During the seasons of 1902 and 1903 the moraine was traced from Great Falls to a point east of the Little Rocky Mountains. Its course is very irregular, being influenced in great measure by the three groups of mountains and the great valleys between them. The moraine was followed for a distance of about 510 miles, in which distance it exhibits many phases of moraine topography. While to trace it in detail throughout its length and to describe every turn and twist and lobe would be a profitless repetition of what is better shown on the map, some of its features deserve special mention.

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[a] Bull. Geol. Soc. America, vol. 7, pp. 65-66.

[b] Map accompanying report on Bow and Belly rivers: Geol. Survey Canada, 1882-1884.

Doctor Dawson traced and mapped its western limit from a point some hundreds of miles north of Calgary to Waterton River, finding it at different heights and at varying distances from the mountains. The remainder of the drift, comprising the part south and east of the Waterton, will be considered here.

The terminal moraine of the continental ice sheet crosses Belly River about 10 miles north of the line. It consists of a sharp ridge, in front of which there is no outwash or valley train. Within the terminal ridge there is a well-defined ground moraine, which, at this point, is 4,163 feet above sea level.[a] Between the Belly and St. Mary rivers the edge of the drift is in places attenuated. The ice sheet pushed in from the northeast and surrounded but did not cover an irregular series of foothills which trend in an irregular line between the two rivers. These hills are about 800 feet above St. Mary River. Their tops and slopes for about 400 feet from the summit are covered with quartzite gravels, below which appear the crystalline bowlders characteristic of the drift of the Keewatin ice sheet. Small lakes dot the surface and the topography is hummocky and irregular.

From the top of one of these hills at the edge of the drift the country covered by the northeastern drift can easily be distinguished from that covered by the mountain drift by the number of its lakes and ponds. To the north many small bodies of water may be seen, while to the south, nearer the mountains, there are but few. The local mountain glaciers were eroding and not depositing, and as a result but few morainal depressions were formed, so that the line of abundant lakes marks approximately the edge of the northeastern drift. The moraine between Belly River and Lees Creek shows well developed kettles.

In the St. Mary basin the ice pushed farther south than on either Belly River or Lees Creek. The moraine crosses the St. Mary just north of the line. One-half mile east of the river it swings south of the forty-ninth parallel, and for a distance of 3 or 4 miles lies in the United States. The boundary monument on the ridge just east of St. Mary River is built of the crystalline bowlders of the moraine. The ridge south of this point was not glaciated, a fact strikingly shown by the contrasting topography of the two portions of the ridge. The region within the moraine at this point might well be called the "lake country." One standing on the northern edge of the ridge just mentioned may count 120 lakes and ponds without stirring from one position. These bodies of water vary in extent from a few square yards to several acres. Many more may exist in this area, though invisible from this position on account of the numerous glacial hills and hummocks. In Willow Creek Coulee, east of the ridge just referred to, the ice pushed as far west as Galbraith's ranch and as far south as Milk River Ridge, which rises 400 to 500 feet above the valley of Willow Creek. At this point the ice did not push south over Milk River Ridge but deposited its moraine along the northern slope. In places the ridge was dissected by pre-Glacial streams, and into these valleys the ice pushed to the very banks of Milk River. This happened in McCloud Pass and in the pass farther northeast, known as Whiskey Gap. West of the McCloud-Fort Benton trail the moraine assumes a ridge-like form 60 to 80 feet high and 100 yards wide at the base. At this place there are splendid examples of kettle configuration. The bowlders are numerous and of the crystalline type, though large bowlders of mountain origin are plentiful. This moraine resembles more than any other seen during the summer that formed by the Green Bay lobe, especially the portion of it developed in the vicinity of Baraboo, Wis. Northeast of this point the ice reached the flat top of Milk River Ridge and spread over it to the south, forming a wide moraine characterized by lakes, undrained depressions, and hummocky topography of strong relief, the difference between the tops of the knolls and the bottom of the kettles in many cases being 120 feet. At the point where the moraine swings to the top of the ridge it has an altitude of about 4,720 feet, and at a point 6 miles to the west of about 4,300 feet; this gives a slope of 70 feet per mile to the edge of the ice of the northeastern ice sheet.

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[a] Bench mark Canadian Survey.

Although the ice reached the summit of Milk River Ridge it did not move for any considerable distance across its plateau-like top. The ridge separated the ice into two parts, one lobe entering St. Mary Valley while the main sheet was forced farther east, causing a great reentrant to be formed. If Milk River Ridge had not been present, the ice would undoubtedly have extended much farther into the United States. The ice crossed the forty-ninth parallel again in longitude 120° 20′, having a general northwest and southeast direction.

From the boundary line to the Great Northern Railway in the vicinity of Baltic the relief of the moraine is pronounced, the difference in height between the hills and hollows being often 100 feet and sometimes more. The edge of the drift north of the railroad is associated with outwash plains and valley trains. In the valleys considered up to this time the slope has been toward the direction from which the ice was moving; that is, the ice moved up the valleys. Under such conditions valley-train deposits were impossible, but here the slope was south and west into the Cutbank Creek and away from the ice edge.

Just north of Baltic the moraine is not so well developed as nearer the Canadian line. The lakes are shallower, and the topography more of the swell and saucer type. At Baltic the moraine is interrupted; the gap continuing to a point south of Two Medicine River. In this interval bowlders and till are present, but the edge of the drift is not in the form of a ridge. Instead it is spread out in a great sheet, with occasionally a very shallow basin and rolling topography. It is entirely possible that back from the edge of this drift sheet a ridged moraine will be found, as is the case on the banks of the Missouri. The edge of the drift crosses Cutbank Creek 5 miles below the railroad bridge at Cutbank and Two Medicine River about 7 miles west of its mouth. Along Cutbank Creek and Two Medicine River bowlders not associated with till line both banks of these streams and their tributary coulees. The till once present has been removed by the action of wind and wash.

The moraine south of Two Medicine River consists of a broad, undulating till sheet which is much more moraine-like than that to the north of the river, but far inferior to that north of the railroad. A well-defined moraine of pronounced topography is not found again until the Pondera basin is reached, this basin being a large reentrant in the plateau between Dry Fork of Marias and Muddy rivers. Between the ridges facing the north and south sides of the basin the ice is pushed to the west, and the moraine becomes once more well defined. The lakes are as numerous as in the moraine near the forty-ninth parallel, while the general roughness of the surface is even more pronounced. At its greatest westward extension the ice is pushed sharply against the bluff which limits the basin on the west; at its southern edge it did not reach the ridge but left its material piled in the form of a high moraine one-fourth of a mile north. The drainage during the time the ice was present was between the moraine and the plateau to the southeast along the edge of the ice. The habit of the ice of pushing for miles into a valley and of not occupying the ridges, though they are but 100 to 150 feet above the level of the moraines, is characteristic. In the Pondera basin the ice extended for 5 miles between ridges 150 feet high, but not once in the distance did it reach their tops. Reasoning from these data the slope of the surface could not have been more than 30 feet per mile. The tendency also of the edge of the ice to move around buttes, leaving deposits on all their sides but not covering their tops, is also characteristic.

Five miles east of the western edge of this basin the ice reached the top of the ridge north of North Fork of Muddy River, and extended across it in a general north-south direction. While not so well defined as the edge of the drift in the Pondera basin, the moraine on the higher level is distinct, consisting of a broad, flat ridge with many shallow depressions containing water. At the southern edge of the flat the moraine turns abruptly to the southwest and runs along the north bank of the Muddy. In this valley is seen one of the best examples in Montana of a striking terminal moraine. There is no well-marked terminal ridge, but the valley north of the creek is one great expanse of hummocks and kettles. The topography is so rough that wagons could cross this section of the country only with the greatest difficulty, while without a compass one not familiar with the region might easily be lost. A mile south of the Kropps ranch, in T. 26, R. 3 W., the ice edge turned abruptly toward the west and filled the valleys of the Muddy and the Teton with a drift sheet of considerable thickness. The western edge of the ice lay across the valley a few miles west of the one hundred and twelfth meridian, and crossed Teton River a few miles east of Choteau. Here its farther southern progress was checked by the Teton Ridge, which is about 500 feet high and extends in a general northeast-southwest direction, and which held in the ice as far east as the Great Falls and Canada Railroad. The ice crossed Teton River in T. 24, R. 3 E., and on the slope south of that river deposited morainic material to the height of 220 feet. Above this level, which is the upper limit of the crystalline bowlders, and on the top and the slope of Teton River Ridge there is gravel composed of limestone, sandstone, and quartzite pebbles. These gravels are not glaciated, and belong to the quartzite gravel formation.

Eight miles due south of Brighton there is a break in Teton Ridge, through which the Great Falls and Canada Railroad passes. At this point the ice pushed through and for the first time deposited material on the south slope of this ridge. Not only did it push into the pass, but it also covered the ridge east of the railroad, a fact easily seen by the difference in topography between the east and west portions of the ridge.

The character of the moraine changes abruptly after it passes over Teton Ridge. There is no longer a well-defined ridge-like edge, but more often a low, broad rise, usually too slight to be noticeable. The drift in the pre-Glacial valleys south of the Missouri and east of Great Falls is 100 to 200 feet thick. Near its edge the drift is usually thin, but along Belt Creek, in sec. 30, T. 21, R. 7, it is 250 feet thick. In many places in the valley of Belt Creek and in the valleys of the neighboring streams there are cuttings of over 100 feet into the drift which do not reach the underlying sandstone.

The moraine swings southeastward from Great Falls to a point north of Belt. Here the Highwood Mountains caused the ice to turn to the north, hence the moraine from Belt Creek runs in that direction for 15 miles. Turning then to the east, it crosses both Belt and Highwood creeks and follows in general the north bank of the Sag to Arrow River. In this part of its course the moraine, where found at all, is low, broad, and of the swell-and-saucer variety, with shallow lakes. The drift is in most places less than 30 feet deep. The same type of moraine continues as it swings along the west bank of the Arrow, but for some distance east of the Missouri there is no ridge of any kind and only here and there a thin ground moraine.

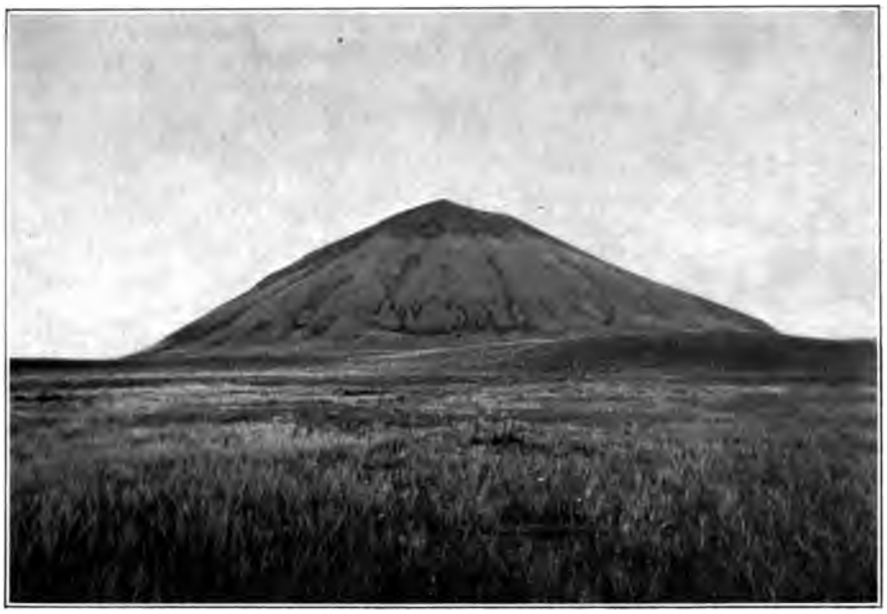
On the southwest side of the Bearpaws, a bowldery ridge with many lakes is again encountered. From this place the moraine swings around the Bearpaws, nearly encircling them (Pl. IV, *A*) and exhibiting at every point a moraine as well defined as that seen along the north slope of Teton Ridge. On the northern slope of the mountains the ice pushed into the foothills and reached an altitude of 4,250 feet. Here, also, the edge of the ice developed many irregularities, due to the great number of valleys. This is shown by the irregular contour of the moraine.

A lobe of ice pushed south between the Bearpaws and the Little Rockies into the valley of Little Rocky Fork Creek. The moraine north of the latter group of mountains does not approach as close to the foothills as it does in the case of the Bearpaws. It lies about 7 miles north of St. Paul's Mission and runs directly east until T. 26, R. 26 is reached, where it turns abruptly southeast and continues in that general direction until all morainic form is lost in the breaks of the Missouri. South of the Missouri, in the valley of the Big Dry, the edge of the drift sheet was traced for 60 miles, but no moraine was found.

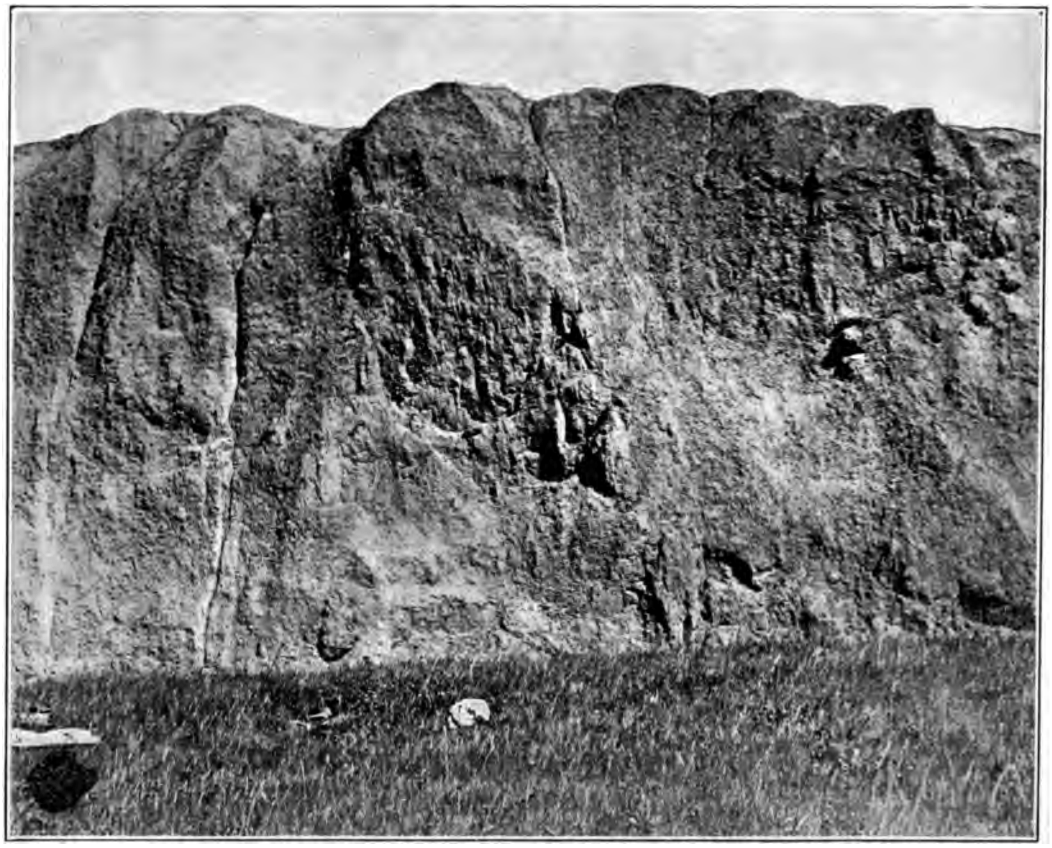
LATER MORAINES.

On the east bank of the Missouri south of Floweree a later moraine, rather well defined, may be made out. In front of the moraine the relation of the stratified drift (till and lacustrine clay) is so complex as to suggest an oscillatory ice edge and much water.

North of the Great Northern Railway and near the divide between Teton and Missouri rivers occurs a second later moraine, which exhibits some unusual features. The edge of the ice advanced into pre-Glacial valleys leading north to the Teton and filled them with drift. The post-Glacial drainage has established itself along these old drainage lines, and the moraine appears to be the divide between the Teton and the Missouri, just as the ridge which it now caps was the divide between the pre-Glacial Teton and the pre-Glacial Missouri. Along this ridge the moraine contains many soft and friable sandstone erratics, which were doubtless plucked from Teton Ridge, lying to the north. Bowlders of local origin are not common in the drift. The soft sandstone over which the ice moved during the last hundred miles of its course yielded but little material, and even this is not so sandy as might be expected. From all indications the ice sheet was not only



A. EAGLE BUTTE NEARLY ENCIRCLED BY MORAINE OF NORTHEASTERN ICE SHEET.



B. TILL SECTION 100 FEET HIGH ON MUDDY CREEK.

Note the absence of bowlders.

incapable of any considerable amount of erosion at its edge, but it deposited material over such formations as the quartzite gravels without disturbing them.

This moraine may be traced, with few breaks, directly across the country from Teton Ridge to the Bearpaws. It is better developed than the terminal moraine, which, while having the essential elements of the kettle moraine, often shows them in a feeble state of development. South of Tunis the moraine is between 3 and 4 miles wide and is covered with lakes and lake basins, some of which extend 50 feet below the general level. This moraine is again seen, though not so clearly defined, along the north bank of the Missouri, near the mouth of the Teton. Between the headwaters of Big and Little Sandy creeks there is another excellent example of morainic topography, continuing to the foot of the west slope of the Bearpaws. North on the ground moraine there are occasionally ridges, never more than a few miles in length. These were doubtless caused by the halting of the ice for a short period, but they are not sufficiently continuous to be mapped as moraines.

CHARACTER OF THE DRIFT.

The material carried by the ice was of four kinds—crystalline erratics, small pebbles of mountain origin, sedimentary rocks derived from the plains over which the ice passed, and a matrix composed of sand and clay. The crystalline erratics are of such variety as to furnish specimens of the whole rock series. In a small area, not over 5 square yards in extent, the following rocks were found: Limestone, sandstone, shale, coal, granites (both fine and coarse grained, and with different percentages of quartz and feldspar), syenites, diorites, basalts, and hornblende, mica, and garnetiferous schist, and all gradations between these and gneissic rocks.

The granite and the syenitic rocks predominate. Basalts and rocks containing a large proportion of the ferromagnesian minerals are not so common. There seems to be very little change in the variety and the nature of these bowlders throughout the length of the moraine. Limestone is more common in the northern part and sandstone occurs more frequently in the southern part. The character of the crystalline bowlders remains the same. The ice must have passed over a wide extent of country, for the nearest outcrop of crystalline rock is 700 miles distant.

To these rocks may be added those which are of mountain origin and which make up from 5 to 25 per cent of the bowlders of the drift. Originally they belonged to the quartzite-gravel formation, and were picked up by the ice from the northeast and incorporated in its drift.

The crystalline bowlders are common on the surface of the drift, occasionally occurring in such numbers as to cover the ground. In some post-Glacial cuts, bowlders from 1 to 4 feet in diameter are accumulated in the bottom of the channel to a depth of 5 to 10 feet. In the body of the drift a large crystalline bowlder is seldom seen. Small crystalline fragments and quartzite pebbles are found, but even these are uncommon. The explanation of the position of these bowlders on the surface of the drift has been given by Prof. R. D. Salisbury.[a]

The great body of the drift is a hard, sandy clay, which as a rule is unstratified and stands in vertical faces where trenched by streams (Pl. IV, *B*). Its thickness is variable. On Belly River an exposure of till 120 feet thick was measured; near Baltic, north of the railroad, post-Glacial drainage has cut 100 feet into the drift without reaching the underlying sandstone; on Two Medicine River exposures 50 to 75 feet thick are seen, and on the Teton drift banks 150 feet high border the river. In the ground-moraine belt the drift is not only thin, but in places is entirely absent. Between the moraine and the Sweetgrass Hills the drift is frequently wanting.

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[a] Jour. Geology, vol. 8, pp. 426-432.

ICE SURFACE.

Height.—The edge of the ice stood at various levels during the time of its greatest extent, a few of the more prominent elevations being as follows, aneroid determination:

Approximate height of edge of ice.

	Feet.		Feet.
Milk River Ridge	4,720	Bearpaw Mountains	4,250
Baltic	3,900	Muddy Creek	3,500
Ridge south of Baltic	4,000	Teton Ridge	3,800
Two Medicine River	3,800	Highwood Mountains	4,200

Slope.—As has been noticed, the slope of the surface of the Keewatin ice sheet was not great. In the Pondera basin the slope was about 30 feet to the mile; on Teton Ridge the slope, much less exactly determined by the slope of the moraine, was about 40 feet per mile, and on the slope of Milk River Ridge it was 50 feet per mile. The most satisfactory determination was made between the Sweetgrass Hills and the edge of the ice to the west. A careful examination of these buttes showed conclusively that they were not covered by the ice sheet, but that they stood as great nunataks about 2,000 feet above its general level. Not only were they not covered by the ice of the Keewatin ice sheet, but there is no evidence that they were locally glaciated. The ice from the northeast, when it reached them, was near the end of its long journey, and was a depositing rather than an active body. On the west, north, and east sides of West Butte a well-defined terminal moraine is banked against the slope. On the south side there is no such terminal moraine, and for some distance south the country is driftless. The ice, divided by the butte, did not come together till it reached a point about 2 miles south of its foot. The moraines left by these two ice edges as they circled the butte and pushed south over the plain are well defined. The moraine on the west slope of the butte is 1,200 feet above the plain; along Milk River on the north side it is 1,500 feet, and on the southeast side it is 1,300 feet. This, then, would make the average thickness of the ice about 25 miles from its edge. In this distance the slope of the upper surface of the ice averaged about 50 feet per mile. On the southeast side of West Butte the slope of the ice, as determined by the slope of the moraine, was 70 feet per mile. Thus it is seen that along the edge of the ice the slope was low, due in great measure to the level plain over which the ice traveled.

DRAINAGE.

LAKES.

Character of the lakes.—The relation of the ice to the river valleys was such that the formation of lakes in front of the ice was inevitable. These lakes may be divided into two classes—those dependent on the ice as a barrier and those lakes. The western edge of Teton Lake was near Bynum and Choteau, in Muddy and Teton valleys, respectively, and its southern edge was against Teton Ridge.

Lake in Missouri River Valley.—Between the Teton and the Missouri River basins a lake of large size existed, its waters extending into the valleys of Missouri and Sun rivers and covering the lowland between the two. Square and Round buttes were islands situated at the extreme western edge of the lake; around them, as around all the other hills and buttes in the neighborhood, are found crystalline bowlders at approximately the same elevation. Some of these are large; the exposed part of one found near Ulm on the Ulm-Great Falls road measured 8 by 4 by 4 feet.

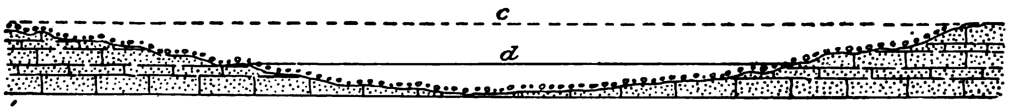

FIG. 3.—Ideal cross section showing relations between the two lake deposits in the Missouri Valley west of Great Falls. *c*, Level of the more extended lake; *d*, level of the more restricted lake.

As will be seen from the topographic map of the Great Falls and Fort Benton areas (Pl. V), this lake had a very irregular extent. The level of the water during the maximum stage of lake development was between the 3,800 and 3,900 foot contour lines. At this level bowlders characteristic only of the northeastern drift are found, few in numbers in the smaller and more distant coulees, but numerous in the valleys in which floating ice could easily enter and be carried about by the wind and currents. The waters of this lake extended for a considerable distance up both Smith and Missouri rivers, but the upper valleys of the two streams are canyon-like, with high walls that afford no resting place for bowlders even if the ice could have made headway against the swift current of the mountain streams.

The bowlders are not found on all parts of the area mapped as covered by water, for they do not appear on the flood plain that extends along both sides of the Missouri. This plain was formed when the waters were held back by the morainic dam, forming a restricted lake, the area of which is essentially that along the Missouri and its tributaries below the 3,400-foot contour line.[a]

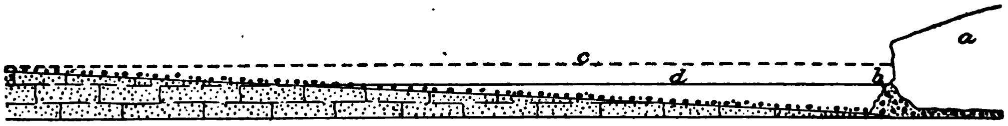

FIG. 4.—Ideal longitudinal section showing relation of the two lake deposits to the drift dam and the ice dam. *a*, Ice edge; *b*, moraine; *c*, level of the more extended lake; *d*, level of the restricted lake.

The relations between the deposits of the two lakes are shown in figs. 3 and 4.

The deposits of the more restricted lake consist of a finely laminated clay, which when dry is hard and cleaves like shale. When wet it becomes soft and pliable and would make an excellent molding clay. Interstratified with the clay are small crystalline pebbles one-fourth to one-half inch in thickness. They usually consist of quartz or feldspar crystals, or of small fragments containing several minerals, showing that the rock from which they were derived was granite,

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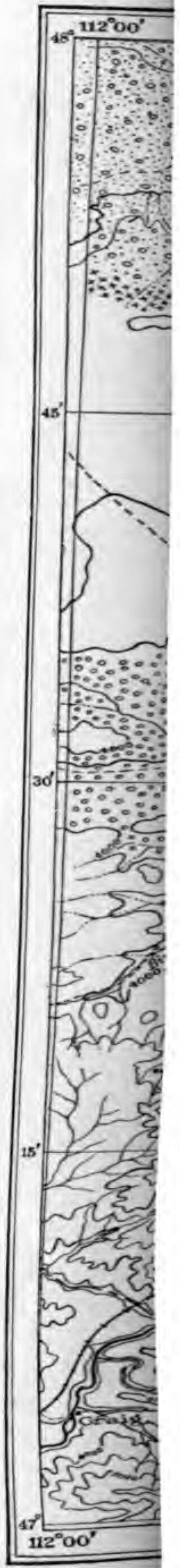
[a] Shown on Pl. V by unshaded area along Sun and Missouri rivers.

U. S. GEOL



RIVERS.

EFFECT OF MOUNTAIN GLACIERS.

The ice deploying from the mountain valleys had but little effect upon the pre-Glacial courses of the more important streams. Small valleys that were tributary to the main watercourses were blotted out, and after the retreat of the ice the change in topography forced the drainage ways to follow new courses. In some parts of its upper course Cutbank Creek was crowded northward by the ice, and its valley was partly filled with valley trains, in which the present streams have cut their channels, though the cutting has in no case been great.

EFFECT OF NORTHEASTERN ICE SHEET.

In contrast to the effect of mountain glaciation the coming of the ice sheet from the northeast changed the character of the drainage markedly. Every river flowing north and east from the mountains was obstructed by the drift, had its waters expanded into a lake, and then, cutting through the morainic dam, found itself superimposed, perhaps some distance from its old bed, upon a body of drift. In most cases the displacement of the stream channel was not great, the post-Glacial streams generally occupying the same valley, though not the same channel.

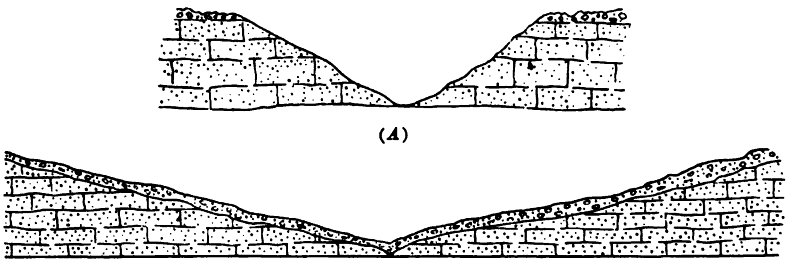


FIG. 7.—Relative size of post-Glacial and pre-Glacial valleys of Two Medicine River. *A*, Post-Glacial valley of Two Medicine River; *B*, pre-Glacial valley of Two Medicine River. In "*A*" the bluffs are covered with till from the Keewatin Glacier; in "*B*" the valley itself is covered by a deposit of till laid down by the Summit Glacier.

St. Mary River.—About a mile north of the international boundary line St. Mary River was superimposed upon a sandstone ledge, its old channel being filled with drift. At this place it has cut a narrow gorge over 100 feet deep. The post-Glacial cutting in the drift near this place has been from 20 to 60 feet. In a number of other places along St. Mary and Belly rivers the streams have been forced to cut into sandstone. In no case near the boundary line was the change in drainage more than a slight shifting of the stream channel.

Milk River.—In pre-Glacial time Milk River flowed in a deep, wide valley, and for this reason was little affected by the drift in the area studied.

Two Medicine River.—West of the place where it is crossed by the terminal moraine of the northeastern ice sheet, Two Medicine River flows in a broad U-shaped valley, which was once filled by the ice from Summit Pass. East of the moraine the stream flows in a post-Glacial valley. It is no longer broad, with gently sloping sides, but is narrow and gorge-like (fig. 7). The walls are nearly vertical sandstone bluffs capped by northeastern drift. The pre-Glacial course of the Two Medicine appears to have entered that of the Marias 5 miles below its mouth in post-Glacial time.

The following cross sections show the width of the Two Medicine at its mouth compared with the cross sections of the valley of the Cutbank above and that of the Marias below (fig. 8). The fact that much more water flows through the valley of the Two Medicine than through that of the Cutbank and that this water has a greater velocity renders the difference in width much more striking. Fig. 7 shows the width of the Two Medicine above and below the terminal moraine.

Birch Creek.—North of the big bend Birch Creek flows between sandstone walls capped with drift. In some sections of the drift the capping is 80 feet in thickness, but usually 10 to 40 feet. The pre-Glacial channel of Birch Creek was not determined. It doubtless led to the Two Medicine or the Marias much farther east than at present.

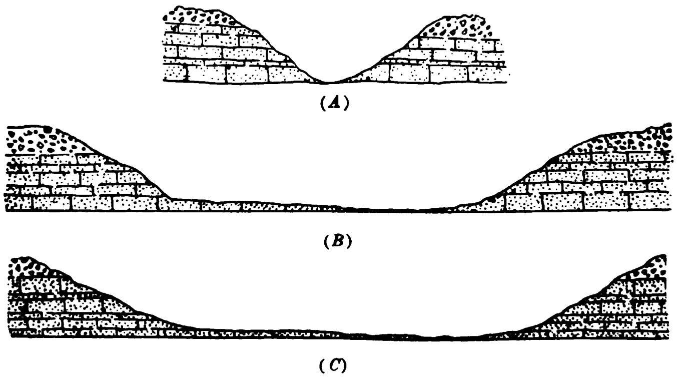


FIG. 8.—Cross sections showing relative size of Two Medicine, Cutbank Creek, and Marias valleys. *A*, Two Medicine Valley just above its mouth; *B*, Cutbank Valley above its mouth; *C*, Marias Valley below junction of the Cutbank and the Two Medicine.

Muddy Creek.—East of the terminal moraine of the Keewatin ice sheet the valley of Muddy Creek is post-Glacial. This part of its valley is 80 to 100 feet deep. Locally the stream has cut through the drift into the sandstone beneath. The old pre-Glacial valley of Muddy Creek is completely hidden, but the general topography of the region shows that its course was not very different from that of the present stream.

Teton River.—In Teton Valley a similar condition exists, and the present channel follows somewhat closely that of the pre-Glacial stream. The Teton has in places cut a valley 150 feet deep in the drift. Lower in its course the Teton has been subjected to more important changes. North of Fort Benton, above the elbow (Pl. III), the Teton flows in a drift-filled valley. The present stream has cut into the modified pre-Glacial valley from 200 to 250 feet. At the north end of the elbow the river turns suddenly to the south and, after flowing for 2 miles in a narrow valley between rock walls, again finds itself in the drift-filled valley of the pre-Glacial Missouri. Here post-Glacial erosion has formed a valley 200 feet deep and a mile wide, similar to that above the elbow. The Teton appears to have been forced into the valley of the Missouri by the drift filling the eastern end of its old channel. This extends from the north end of the elbow through the valley now occupied by Sheep Creek into the Marias. East of Fort Benton the Great Northern Railway has tunneled through the ridge between the Teton and the Missouri. Here the two streams are but half a mile apart, and are separated by a divide 200 feet high, at least 120 feet of which is drift.

Other streams in the area studied were turned from their pre-Glacial courses by the ice, but as in each case the change was closely associated with the change in the Missouri, they will be considered in connection with the pre-Glacial and post-Glacial history of that stream.

Missouri River.—Of all streams in northern Montana, the Missouri was the one most affected by the ice sheet, to which is doubtless due the fact that it is a tributary of the Mississippi and not of the Saskatchewan or the Red River of the North.

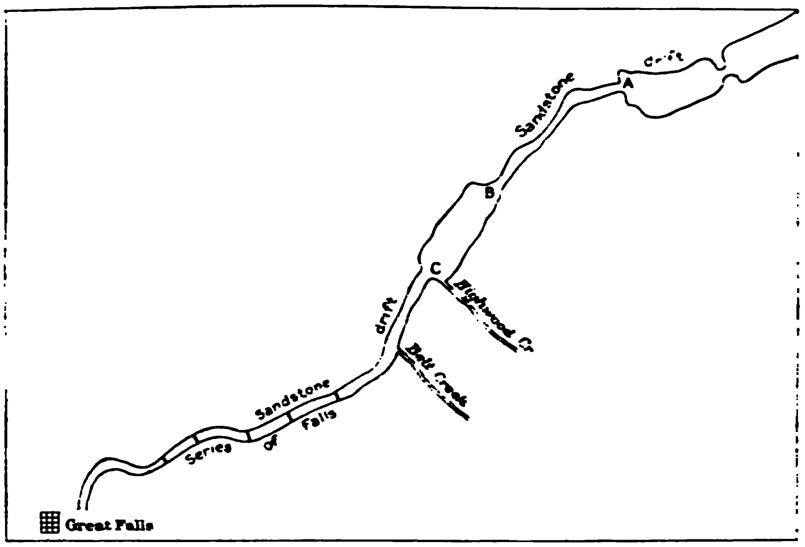
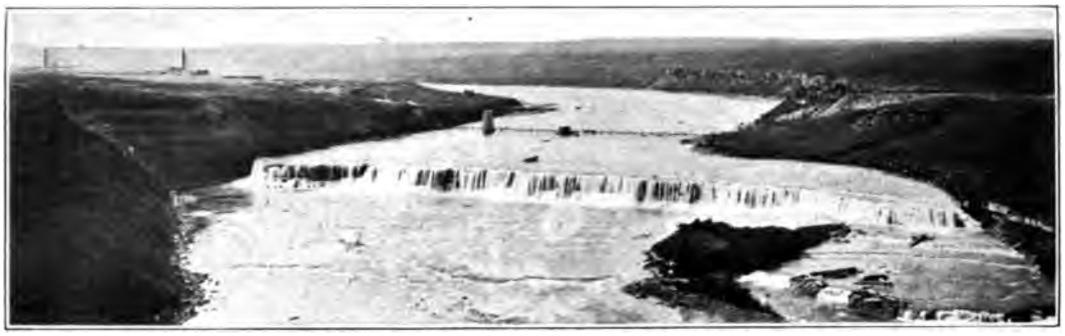


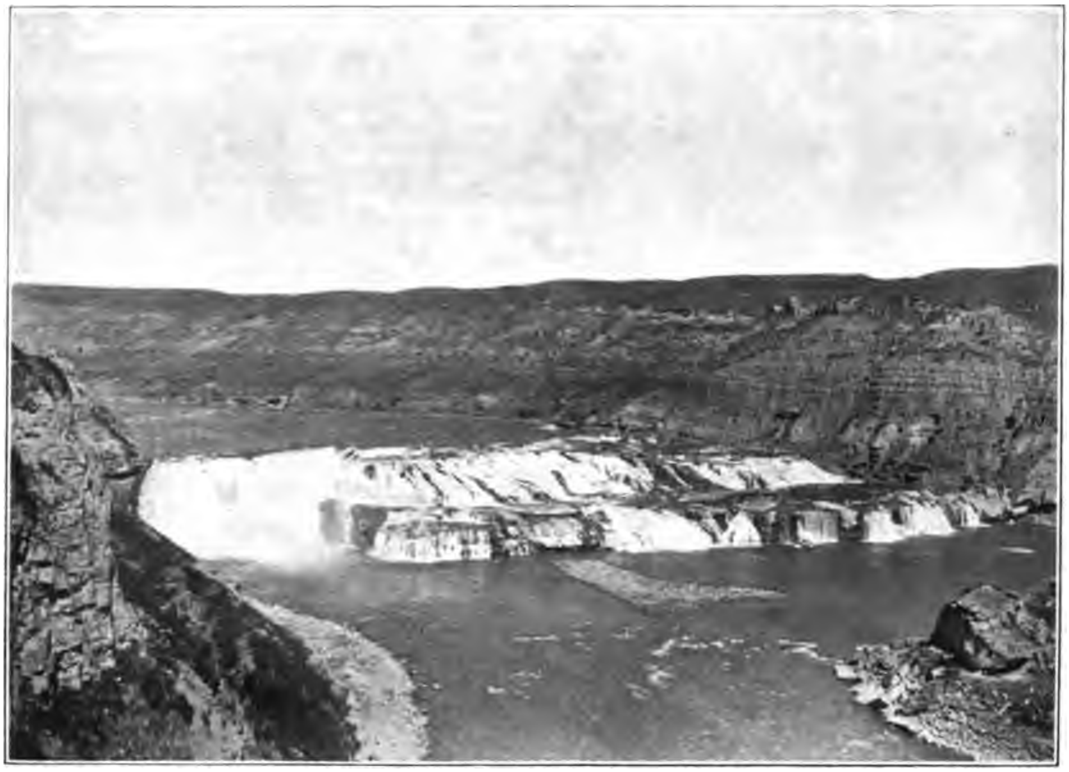
FIG. 9.—Valley of the Missouri, showing post-Glacial cutting in sandstone and drift.

When the old channel of the Missouri became filled with drift, the river was turned from its former course and forced to find a new channel for itself south of the edge of the ice sheet. In some places the post-Glacial stream followed the old valley for some distance until at last, turned aside by some barrier, it was forced to follow a tributary stream across a col into the valley of another river. The changes in the course of the Missouri have been varied and are given in detail.

The river rises in the extreme southwestern portion of the State and flows northeastward. For the first 300 miles it is confined by mountains, but after passing between the main range of the Rockies and the Little Belt Mountains it escapes to the plain. From this place to Great Falls the river meanders over a wide flood plain, flowing 75 miles with a fall of but 85 feet. At Great Falls an abrupt change in the character of the stream takes place. Leaving the plain it flows through a canyon with high sandstone walls and falls 512 feet in 12 miles.



A. FALLS OF THE MISSOURI



B. ONE OF THE FALLS OF THE MISSOURI, SHOWING AMOUNT OF POST-GLACIAL EROSION.

In this part of its course the river runs in a sandstone valley, in which cataracts have developed (Pl. VI, *A*, *B*) because of the harder ferruginous layers found in it. The unequal rate at which the falls have retreated is due to the varying hardness of these layers. It is not known exactly at what point the falls originated, but it was doubtless where the superimposed Missouri found its way over the side of an old valley wall, either into its own pre-Glacial channel or into that of one of its tributaries. This, so far as now known, may have happened at any one of a number of places. At a point near the mouth of Belt Creek the valley suddenly broadens and at the same time turns abruptly to the north (Pl. VII, *A*). Here the river flows through an old drift-filled pre-Glacial valley (fig. 9). The post-Glacial river does not everywhere flow in the old channel but crosses it at all angles. This unconformity of the old channel to the present one is shown in the sections forming fig. 10.

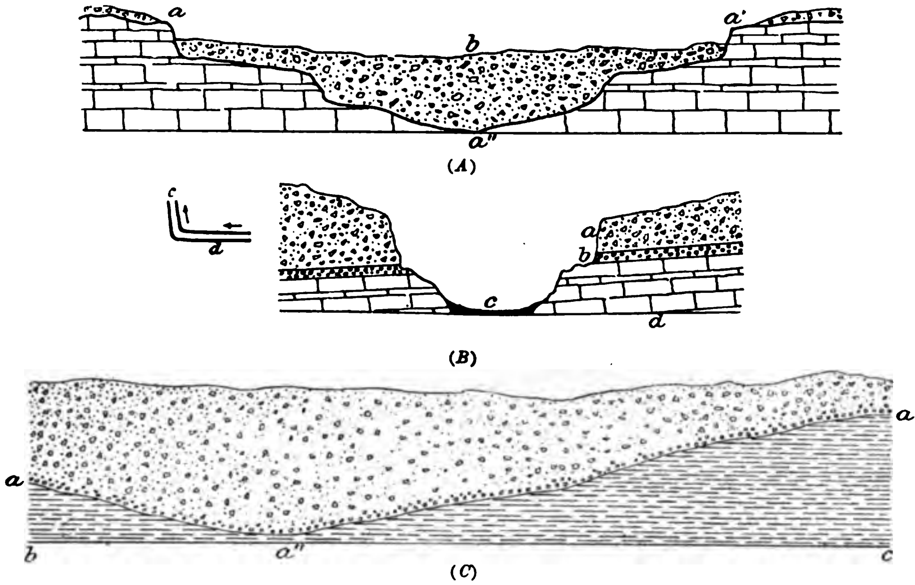
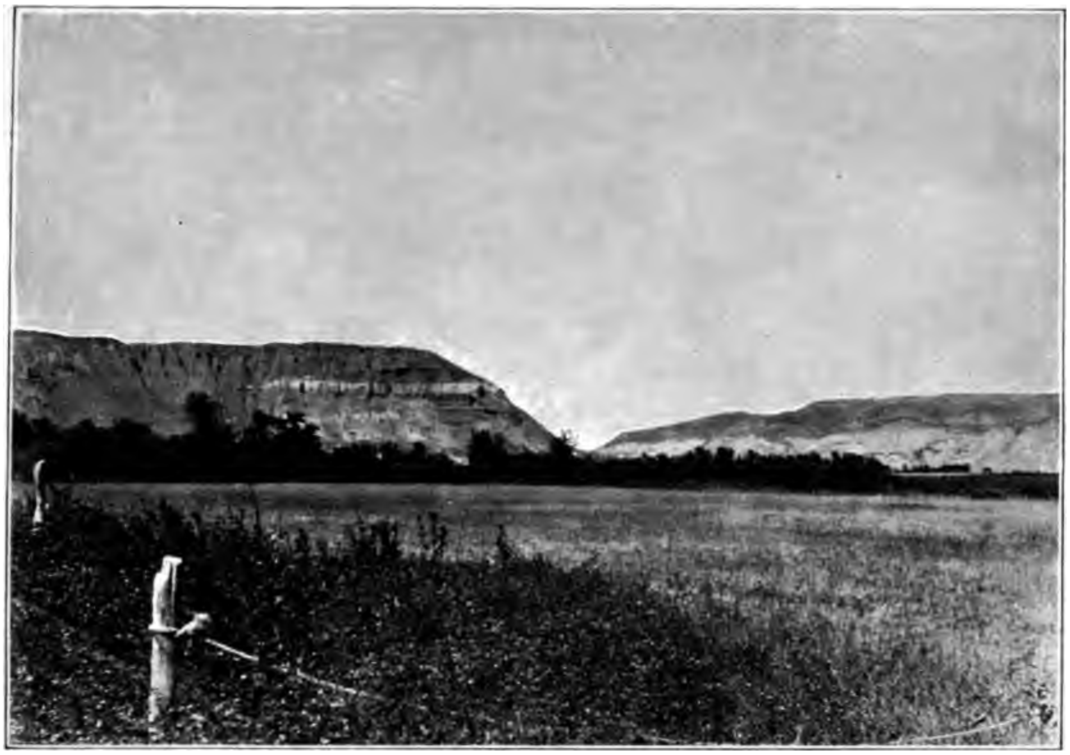


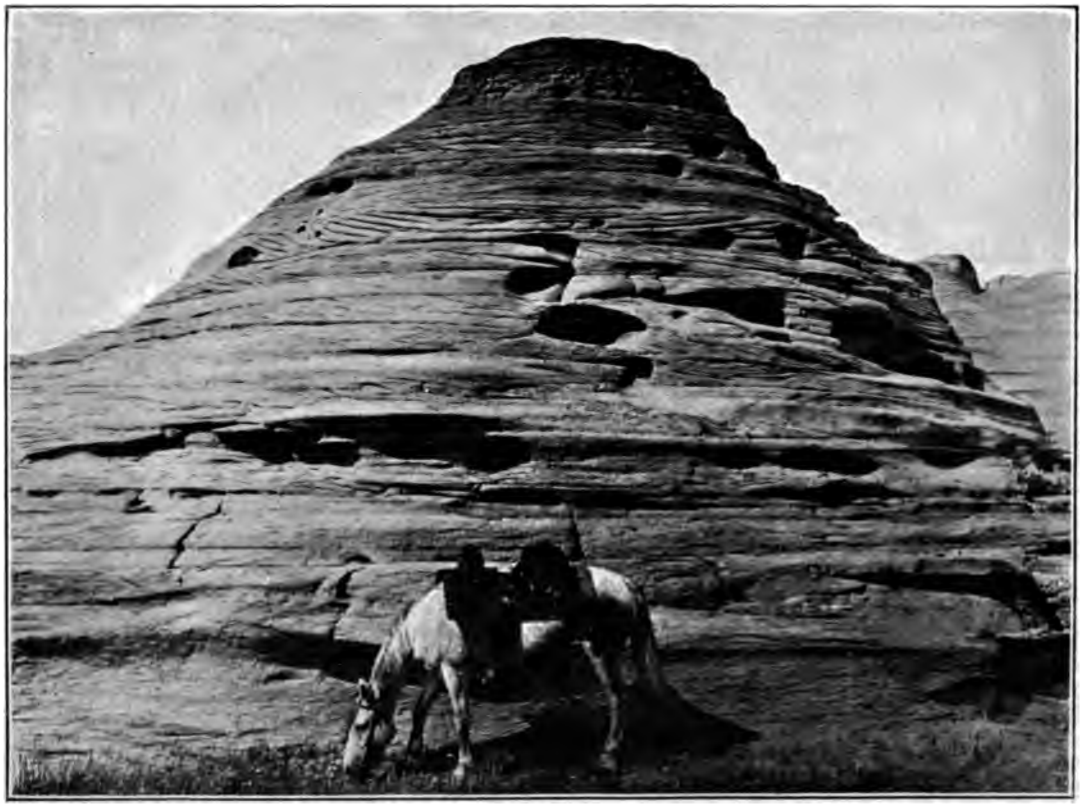
FIG. 10.—Sections showing the pre-Glacial valley of the Missouri. *A*, Old valley of the Missouri, 12 miles wide; *a* and *a'* represent the exposed sandstone bluffs of the pre-Glacial valley; *b* is the drift filling. *B*, Slope of the old valley; *b* is a layer of old river gravels and *a* the drift deposit; the small diagram to the left shows the relation of the river and the exposures. Through these deposits the post-Glacial stream has cut into the underlying rock. *C*, Present course of the Missouri, *b*, *a''*, *c*, cutting across the pre-Glacial channel at a right angle.

At the big bend of the Missouri, at the mouth of Little Sandy Creek, there is another abrupt change in the character and direction of the valley. The river, which has been flowing northeastward, turns abruptly to the southeast. The valley narrows, becomes more canyon-like, and loses its drift walls. The bench on both sides of the stream slopes to the north while the river flows south. At the mouth of Arrow River there is a sudden turn to the east, though the character of the valley does not change. The river continues to flow between high rock walls, with little bottom land, and in a valley which narrows and widens without apparent cause. From the mouth of the Musselshell to that of Milk River the valley is narrow, with walls 600 to 1,000 feet high. Beyond Milk River it takes on the broad, shallow



A. WATER GAP FORMED BY MISSOURI RIVER.

The wide valley has been reexcavated from one filled with drift. The narrows are found at a point where the stream was superimposed on the top of a pre-Glacial sandstone ridge.



B. WIND EROSION NEAR DRY FORK OF MARIAS RIVER.

stream entered the old valley near the mouth of the Highwood, and it was doubtless at this point that the falls originated (fig. 11).

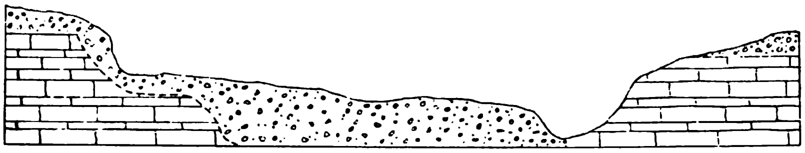


FIG. 11.—Cross section showing the drift in the valley through which Highwood Creek now flows. Looking north downstream.

Into this pre-Glacial valley, situated south of the present stream, flowed Belt and Highwood creeks. When the major stream was diverted to the north these streams were obliged to cut through miles of sandstone to find an outlet.

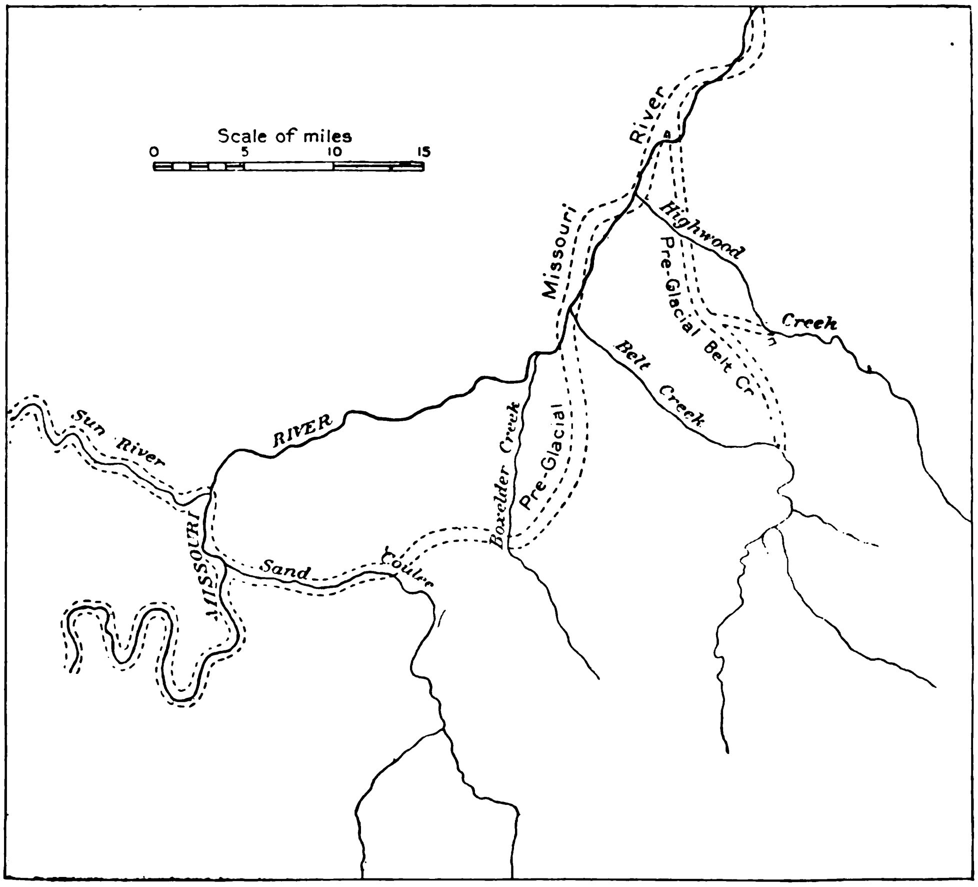


FIG. 12.—Map showing the pre-Glacial course of the Missouri between Sand Coulee and the mouth of Highwood Creek.

The map (fig. 12) shows the relation of these streams to the pre-Glacial Missouri and to the present river.

Into the old valley, now filled with drift, the post-Glacial stream cut its channel, meeting no more serious obstructions than are usually encountered by a superimposed stream. Fig. 13 gives some idea of how the new channel cut across the meanders of the old.

At the mouth of the Little Sandy, the sudden turn to the south, the narrow valley with its rock walls, and the great, wide, drift-filled valley stretching off to the northeast to the Milk River, all suggest that the river has again been diverted. This valley is 35 miles long and is occupied by two streams—the Big Sandy flowing north into Milk River and the Little Sandy flowing into the Missouri. The two streams rise in the same vicinity but are separated from each other by a morainic dam that stretches across the valley 8 miles north of the Missouri (fig. 14).

The thickness of the drift deposit in Big Sandy Valley is not easy to estimate. Near the Missouri, where the river makes its sudden turn, there appears to be 200 feet of till, but this at lower levels may be talus-covered rock. Forty feet above the present level of the river near Blankenbaker's ranch is a bed of river gravels covered by cross-bedded sand. These gravels are found on the top of the sandstone at many other places and consist of smoothed and rounded pebbles of both Rocky Mountain and northeastern origin. The thickness of the drift deposit in this valley north of the Missouri could not be determined. The Little Sandy has cut a channel 60 feet into the drift without reaching rock. From this point to Havre there is no cut of more than 20 feet.

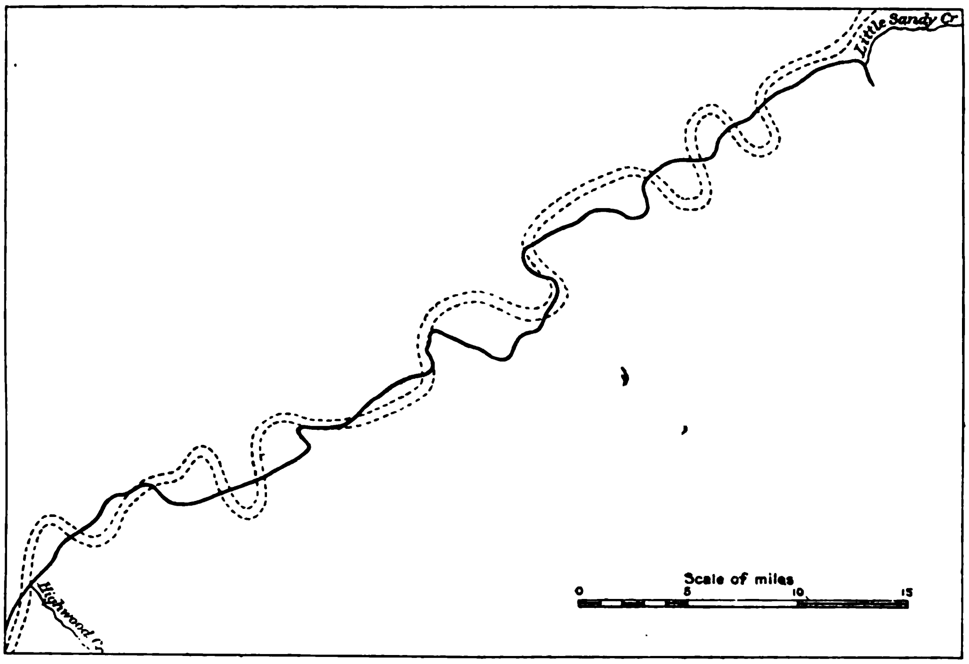


FIG. 13.—Relations of the post-Glacial and pre-Glacial channels of the Missouri between mouth of Highwood Creek and mouth of Little Sandy Creek.

This valley joins that of Milk River east of Havre. South of the town there is a drift filling 140 feet thick. The map gives the relations of the present valleys to the old valley (fig. 15).

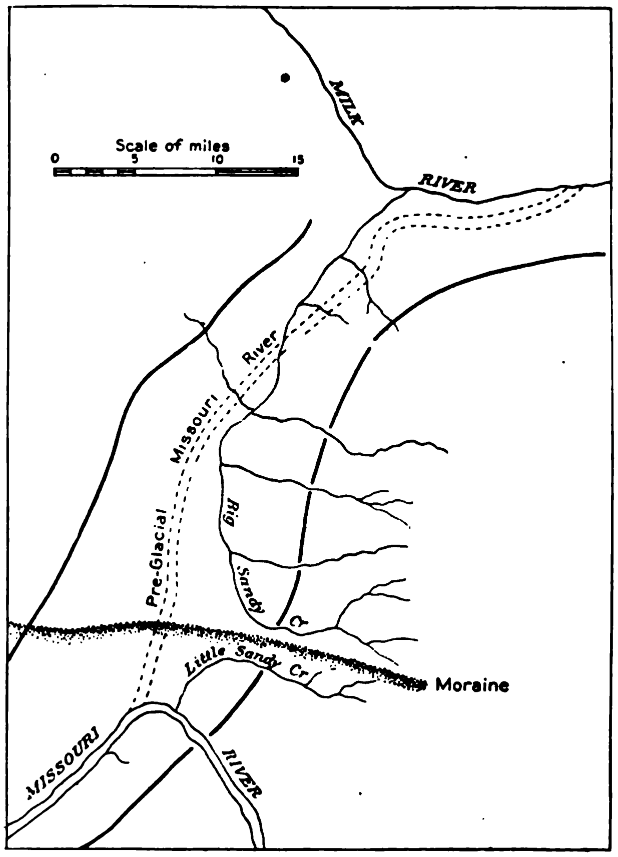


FIG. 14.—Map showing outlines of the great pre-Glacial valley between Missouri and Milk rivers. The map also shows the moraine that forced the river south.

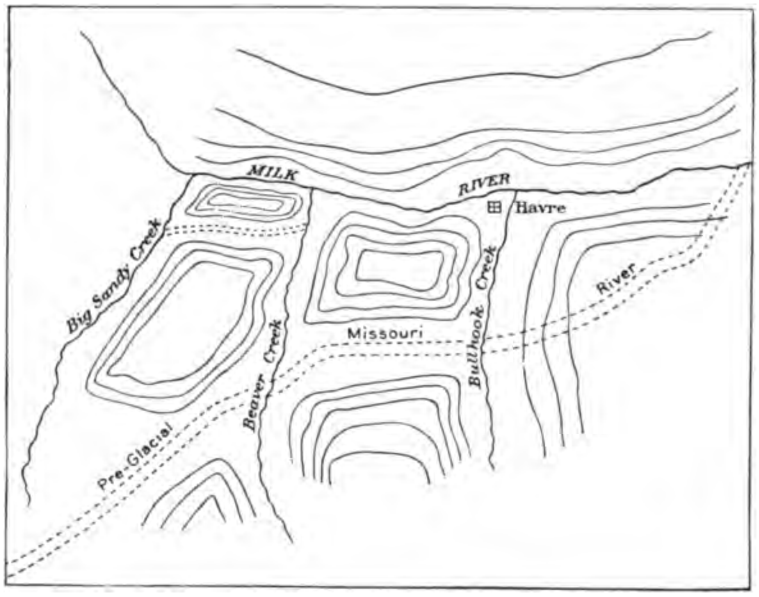


FIG. 15.—Map of the vicinity of Havre, showing the relation of the pre-Glacial Missouri to the valleys of the post-Glacial streams.

The valley of Milk River above its junction with the pre-Glacial valley of the Missouri varies in width from one-fourth to one-half mile, but below the junction becomes much broader, being 2 to 3 miles wide.

South from the turn at the mouth of the Little Sandy the Missouri flows between high rock walls. The bottoms are few and small and the current rapid. The Arrow, the Judith, the Musselshell, and the Dog are tributaries in this part of its course, and each one has been affected by the change in the direction of the trunk stream.

In order to illustrate the conditions under which these various changes took place and the reason for each change figs. 16, 17, 18, and 19 have been prepared.

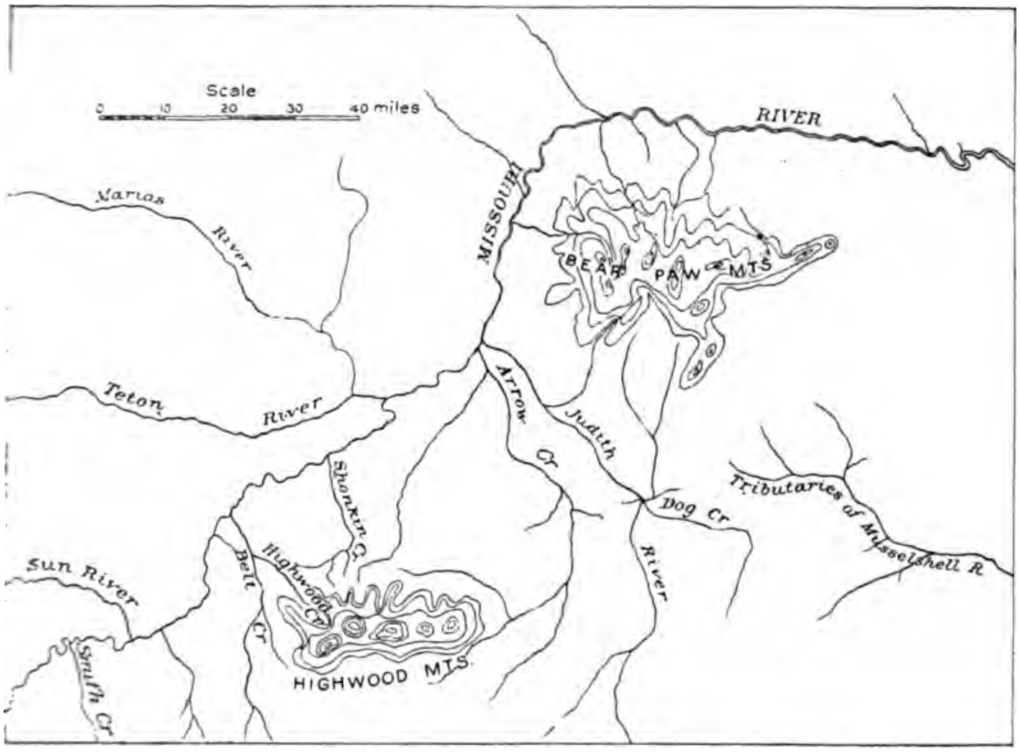


FIG. 16.—Map showing pre-Glacial river system of northern Montana.

Fig. 16 illustrates the pre-Glacial drainage system, fig. 19 the post-Glacial system, and figs. 17 and 18 intermediate stages. Fig. 16 is more or less ideal, for, owing to the weathering of the soft sandstone, valley contours have been greatly modified by the drift, making difficult the work of restoring the minor drainage lines.

The more important changes in drainage caused by the ice sheet appear to be closely connected with the history of the Shonkin Sag, a valley which runs from Highwood Creek to Arrow River. The sag is in places nearly a mile wide and over 500 feet deep. It is entirely independent of rock structure and runs across the present drainage lines at right angles. Another curious feature of its position is that it is superimposed on the northern slope of the Highwoods. It would be

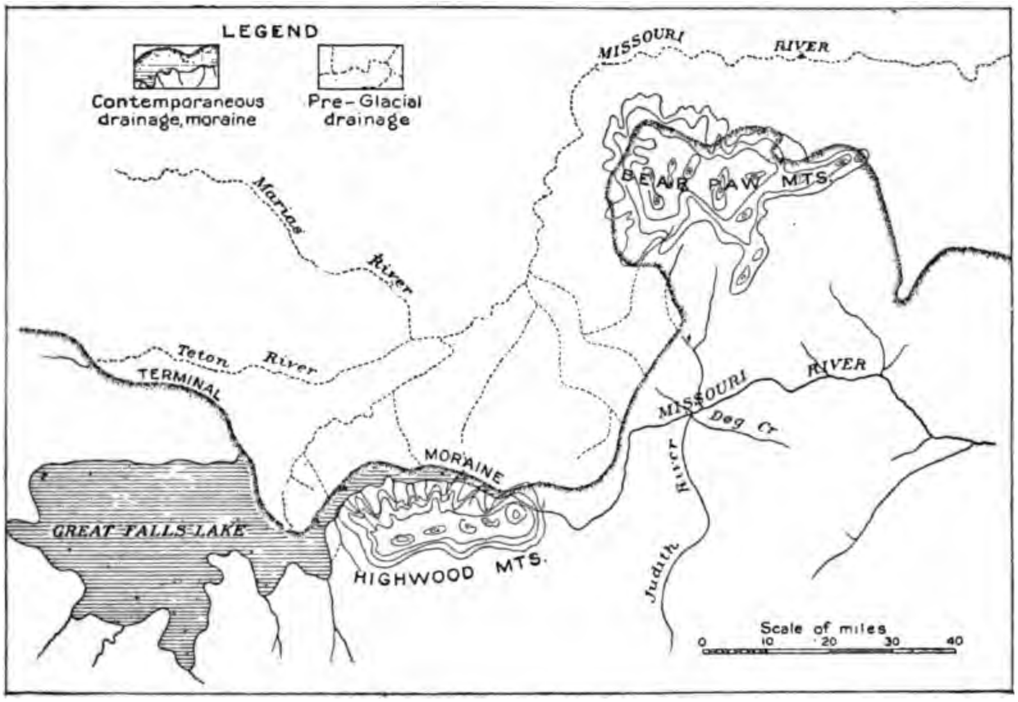


FIG. 17.—Map showing drainage of northern Montana when ice had maximum extent, and also pre-Glacial river system.

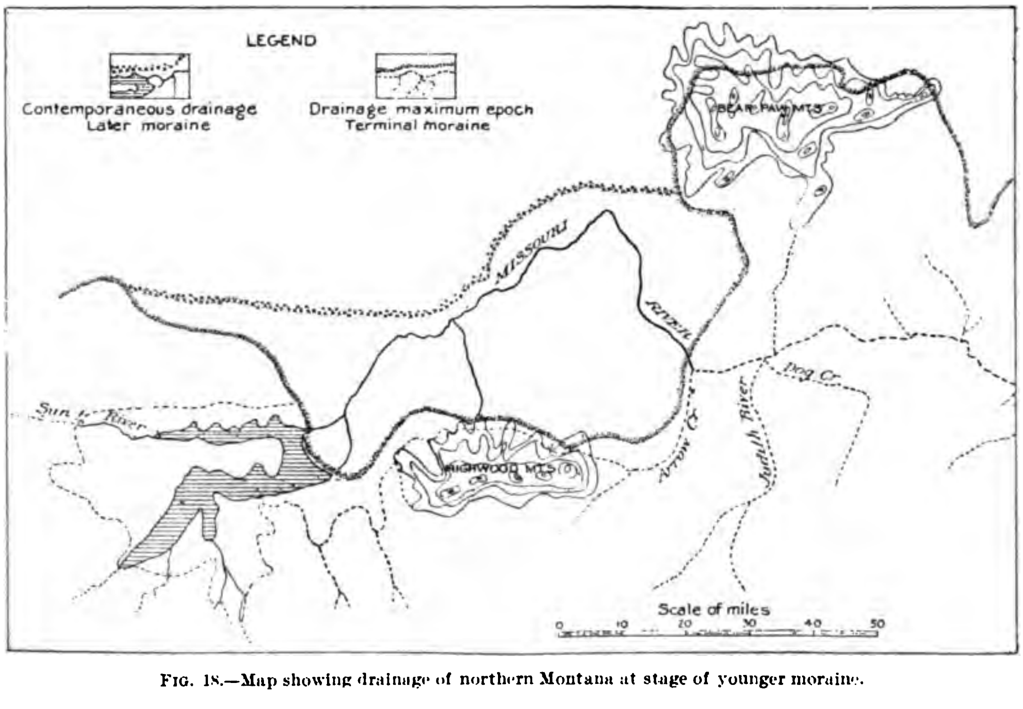


FIG. 18.—Map showing drainage of northern Montana at stage of younger moraine.

mouth of the Little Sandy. This moraine was also responsible for the permanent diversion of the Missouri to the south at the mouth of Little Sandy Creek. With its old channel leading north filled with Glacial ice and drift, the waters found an outlet to the south either through a small tributary to the Missouri from the south, or through Arrow River, which in pre-Glacial time may have emptied into the Missouri at this point. The latter hypothesis appears for many reasons to be the true one. The valley of the Arrow enters that of the Missouri at the present time in such a manner as to suggest that it once flowed north. Not only does the angle at which the two valleys meet suggest this, but the tributaries to the Missouri above the junction of the Arrow indicate that the river formerly flowed northward. The elevation of the bench near the junction of the two streams is greater than any portion of the bench to the north. Either the Missouri at this point is an antecedent stream or the pre-Glacial drainage was through the Arrow north to the Missouri west of the present mouth of the Little Sandy.

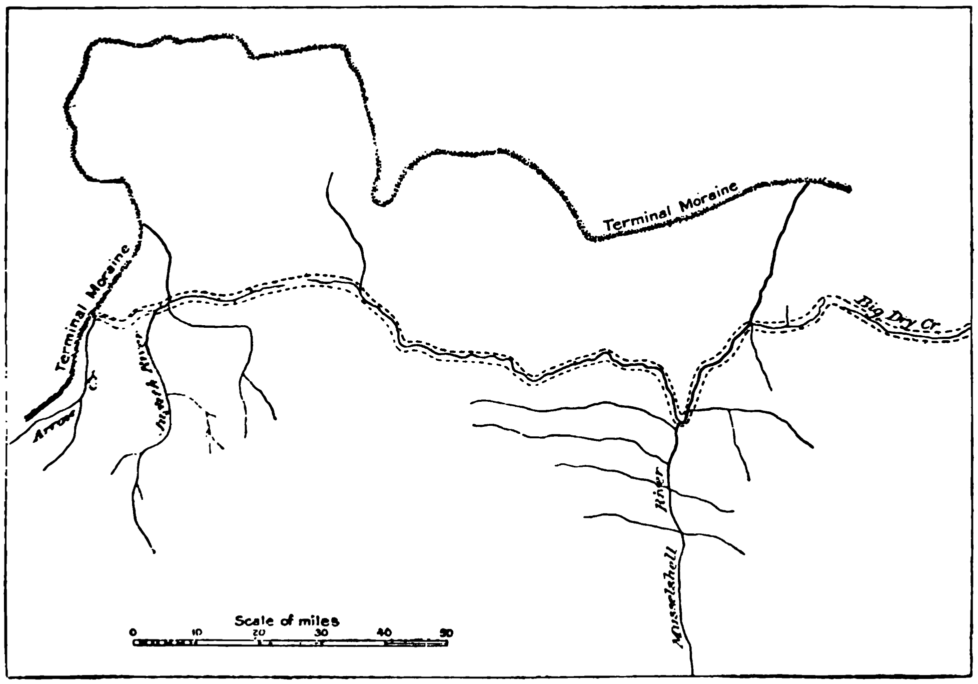


FIG. 23. Map showing in detail how the Missouri was forced across the valleys of Arrow, Judith, and Musselshell rivers.

The waters, finding no outlet south through the Arrow, turned to the east and, following a tributary from that direction, passed over a narrow divide into a tributary of the Judith. This was doubtless the course followed by the waters of the lake that existed while the ice was advancing from the former mouth of the Missouri near Havre until it retreated again beyond Fort Benton. The course for the new stream had already been determined by the drainage from Great Falls Lake. The peculiar course of the Missouri between the mouth of the Arrow and the mouth of the Judith, as well as the shape of its valley, would seem to favor this conclusion. The map shows the relation between the tributaries of the Judith and the Arrow and the valley of the post-Glacial Missouri (fig. 23).

During pre-Glacial time the course of the Judith was northward, joining the Missouri near the mouth of the pre-Glacial Arrow. Since the Missouri was thrown across the Judith at right angles, it has cut 500 feet below the old channel of that stream. This is shown by the great valley that stretches away to the north 500 feet above the level of the Missouri, and by the behavior of the Judith and other streams tributary to the Missouri at this point. Fig. 24 shows the relation between the slope of the old Judith valley and the present slope. The same condition exists also in the valley of the Dog, though in this case it is even more pronounced.

For 30 miles east of the Judith the bench on either side of the Missouri rises gradually, then falls again to the east into the Musselshell system. The Dog flows westward for 25 miles parallel to the Missouri. The other streams also come in at such angles as to lead one to expect them to empty into a river flowing either west or north. East of the divide just mentioned, the tributaries again enter the main stream, following the usual law. It would appear that what took place west of the Judith was repeated east of that stream. The waters flowed eastward through a tributary of the Judith over a col into a tributary of the Musselshell. This stream is also supposed to have flowed north through the Great Lonesome Prairie Valley, joining the Missouri in the vicinity of Saco. The same process was repeated in the valley of the Big Dry. From this point the river again found its old channel and flows in a modified pre-Glacial valley eastward for many hundred miles.

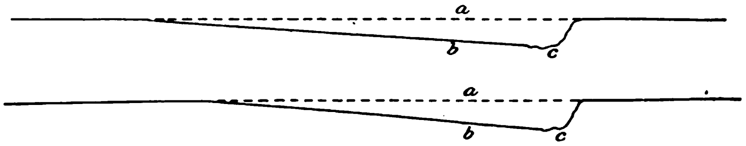


FIG. 24.—Longitudinal profiles of Judith River and Dog Creek valleys. *a*, Level of the old valley; *b*, level of the present valley; *c*, valley of the Missouri. The cutting of the Missouri from *a* to *c*, at the mouths of Judith River and Dry Creek, has caused these tributaries to work back.

On the whole the changes in drainage induced by the ice of the Keewatin sheet in the area studied were not great. If, as Dawson thinks, an earlier drift sheet covered the region, changes in drainage may have been brought about by that more far reaching and more profound than those induced by the later ice.

INTERRELATIONS OF SURFACE FORMATIONS.

THE QUARTZITE GRAVELS AND THE TWO DRIFT SHEETS.

The surface formations of the area have been described in detail. It now remains to consider their relations to each other.

The quartzite gravels may be summarily treated. In the area between the drifts of the two ice sheets the gravel occurs as a surface formation, lying on Cretaceous beds. Near the mountains the gravels are found under the drift of the local glaciers. This relation is seen north of the forty-ninth parallel in the vicinity of Duck Lake and on the high ridge north of North Fork of Cutbank Creek. The sections show a layer of rounded, weathered, quartzite gravel covered by angular striated bowlders, having among them a large proportion of limestone and diorite. In sections exposed along the edge of the Keewatin drift sheet the gravels are likewise found beneath the till. Their relative positions are shown in fig. 29, page 48.

The position of the quartzite gravels makes them older than both the mountain drift and the northeastern drift. Their age, an interesting question because of the conclusions of Dawson upon the subject, will be discussed after the relations of the other surface formations have been treated.

THE NORTHEASTERN AND THE MOUNTAIN DRIFT SHEETS.

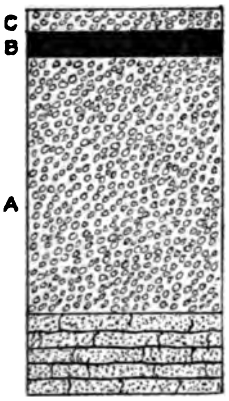


FIG. 25.—Section on Birch Creek. A, Valley train containing striated limestone pebbles, 20 feet; B, soil; C, gravel made up to a large extent of crystalline pebbles.

As already stated, a number of broad valleys have been cut into the Cretaceous rock of the plains. Into these valleys glaciers deployed, forming moraines, outwash deposits, and valley trains. Into these same valleys from the east came the ice from the Keewatin Glacier, which threw moraines across the valleys and formed at its edge various extramorainic deposits. It is the relation of such deposits to each other in the several river valleys that is now to be considered.

In Sun River Valley the moraines of the two ice tongues are about 60 miles apart. Down the stream for some distance from the moraine of the mountain ice extends a valley train. In front of the Keewatin ice sheet there existed in Sun River Valley a large lake, in which lacustrine clay was deposited. The relation between these two formations, if they come in contact anywhere, would give a clue to the relative age of the two ice movements, but, though such a relation doubtless exists, it was not seen in any section along Missouri or Sun rivers. Similar formations are found in the valleys of Teton River and Muddy Creek, but, though a relation between the deposits in front of the two ice sheets ought to be made out in these valleys, in no section was such a relation shown. Gravels are found along these rivers under the lacustrine clay, but they are of soft limestone, without glacial marking, and whether they belong to the valley train or to fluvial deposits of unknown age was not determined.

In Birch Creek Valley, however, the two moraines are only about 18 miles apart. As along Sun River, a glacio-fluvial train extends down the valley of the Birch and into this the stream has since cut a narrow channel. At a number of places along the creek there are exposures showing a thickness of from 20 to 30 feet of these gravels. Although a few of these are striated, the majority have been subjected to so much water action that all trace of glaciation has been removed. Lying on the gravels, and never in or beneath them, are large crystalline bowlders of northeastern origin, which were carried by floating ice on the lake extending along the Keewatin ice edge, and which were scattered at irregular intervals over the lake bottom. Farther east, nearer the terminal moraine of the Keewatin ice sheet, the lacustrine clay appears, also lying on the gravels. Fig. 25 shows the relations of the bowlders and the clay to the gravels of the valley train.

On Birch and Dupuyer creeks and on the tributaries opening into them are many sections which show essentially the same order and deposits. In these valleys, then, we may see the relative age of the two drift sheets as shown by the deposits formed in front of the ice (fig. 26).

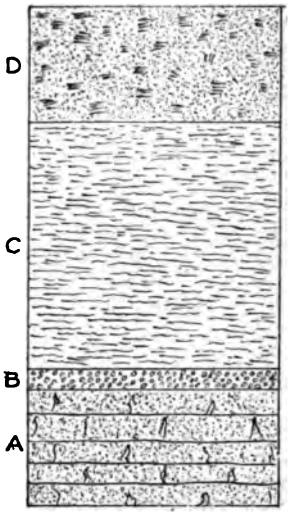


Fig. 26.—Section near mouth of Dupuyer Creek. A, Sandstone; B, valley train from Birch Creek Glacier; C, lacustrine clay containing crystalline pebbles; D, eolian deposit.

In the valley of the Two Medicine also the moraines come close together, and here two very interesting and comprehensive sections are found within 2 miles of each other. The first occurs where the terminal moraine of the Blackfoot Glacier is trenched by Two Medicine River and the second where a meander of the same river has recently undermined a portion of its bank.

The first section (fig. 27) shows that the ice of the Blackfoot Glacier formed its moraine across Two Medicine River and retreated, and then the northeastern ice sheet pushed into the valley and deposited its moraine within a mile of the edge of the mountain drift, while in the lake formed west of its edge lacustrine clay was laid down above the till from the mountains.

In the second section (fig. 28) the 50 feet of till belonging to the Keewatin drift sheet lies above a layer of glacial gravel of mountain origin, which was doubtless deposited at the time the valley to the west was occupied by the mountain ice. Between the till and the valley train two formations intervene. Resting upon the gravel is a layer of sand and clay, part of which was deposited by wind and part by water, and above this layer a bed of lacustrine clay occurs. It would appear that after the deposition of the clay in the lake along the front of the ice, the ice advanced and covered a part of its own lake deposit. In this section the till of the northeastern drift sheet lies above the deposit formed in front of the Blackfoot Glacier.

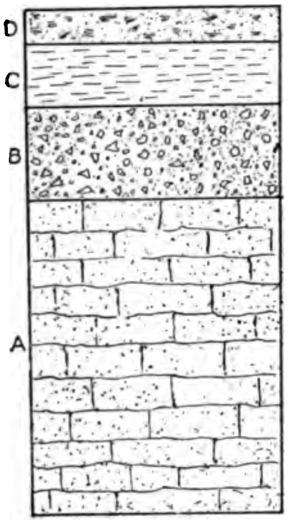


Fig. 27.—Section on the Two Medicine at point where Blackfoot Glacier crossed it. A, Sandstone, 50 feet; B, till formed by Blackfoot Glacier, 15 feet; C, lacustrine clay formed in the lake which existed in front of the Keewatin ice sheet, 10 feet; D, windblown deposit, 5 feet.

We have seen how the ice in the mountains in St. Mary River Valley, after it had crossed Milk River Ridge from north to south, spread eastward, depositing its moraine along the north slope of the ridge. It has also been shown (p. 23) how the Keewatin ice sheet was held back by the same ridge and deposited its terminal moraine along the same north slope.

In the coulee in which Galbraith's ranch is located, near the ranch, the moraine of the mountain glacier disappears under the drift of the northeastern ice sheet.

Although in general the two drift sheets are quite distinct, the line of demarcation is not sharply drawn. The Keewatin drift contains mountain bowlders which were picked up by the ice as it moved westward over the earlier drift sheet. Lying upon the drift from the mountain are fragments of crystalline rock from the northeast, which were carried out beyond the edge of the eastern drift sheet by floating ice. The two drift sheets are not exposed in section in this valley.

In St. Mary Valley proper the mountain ice pushed much farther north. Great argillitic bowlders from the Rockies are found 10 miles north of the forty-ninth parallel in such a position that it is evident that they were left by mountain ice. Others are found on top of St. Mary Ridge, at a point where the ice from the northeast reached the top of the ridge and mingled its bowlders with the mountain drift. Figs. 29 and 30 show significant sections along St. Mary River.

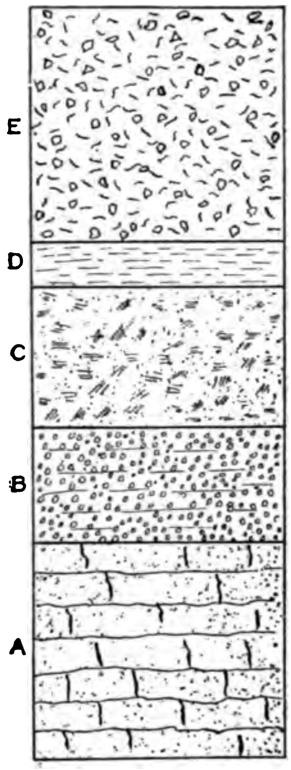


FIG. 28.—Section on the Two Medicine 7 miles west of mouth. A, Sandstone; B, valley train from Blackfoot Glacier, 25 feet; C, eolian deposit, 30 feet; D, lacustrine clay, 30 feet; E, northwestern till, 50 feet.

In the valley of Belly River the contact of the two drift sheets is seen in section. About 10 miles north of the forty-ninth parallel the moraine of the northeastern ice sheet crosses Belly River and swings in a northwestern direction toward Waterton River. Two hundred yards south of the point where the moraine crosses the river, and therefore outside of the northeastern drift sheet, the river has cut through about 60 feet of drift. The lower 30 feet consists of a bed of roughly stratified, somewhat glaciated mountain gravels. Above this is 30 feet of heavy bowlder clay. The bowlders are, without exception, from the mountains, and are ice marked to an unusual extent. At the very top of the section, lying upon the mountain till, but never in it, a few crystalline bowlders are found.

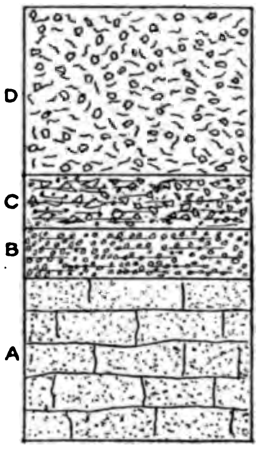


FIG. 29.—Section on St. Mary River, near Sloan's ranch. A, Sandstone; B, waterworn, nonglaciated gravels; C, glaciated, angular pebbles from the mountains, not waterworn to any extent, but apparently part of a valley train; D, till of the northeastern ice sheet, containing many small crystalline pebbles, but no large bowlders; B and C grade into each other; B is evidently a pre-Glacial formation.

It was over such a till formation as this that the ice from the northeast moved. In most of the sections exposed by post-Glacial cutting within the edge of the eastern drift the two tills are mixed, showing that the later ice handled, to a greater or a less extent, the material deposited by the valley glaciers. Only one section, where the line between the two bodies of drift was sharply marked, was seen, though in many places the plane of division could be made out approximately. The drift from the northeast contained but few bowlders, while that deposited by the mountain ice was heavily loaded. In any mixed body of drift, the upper part would contain both crystalline and sedimentary bowlders in small numbers, while the heavy bowlder clay at the bottom of the section, though it sometimes contained a few crystalline bowlders, represented the mountain drift sheet, as far as it could be made out. The talus always present along the banks of the streams often obscured this indefinite division line. Within the moraine, not far from the edge of the drift, the section shown in fig. 31 is exposed. This section is the only one along the banks of Belly River that shows the two drift sheets separated from each other by a definite division line.

Thus, in these river valleys, a definite relation has existed between the two drift sheets—a relation which warrants the conclusion that the Keewatin ice sheet advanced into the region after the deposition of the moraines of the mountain glaciers.

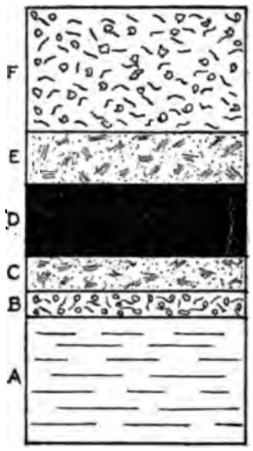


FIG. 30.—Section on St. Mary River, north of Sloan's ranch. A, Shale; B, northeastern drift, 2 feet, containing many decomposed bowlders; C, typical loess, 5 feet, containing concretions, hard shells, and bones of small animals; D, soil, 10 feet, of black clayey loam, consisting of the weathered surface of the lower loess bed; E, loess, 6 feet in thickness, sandy at the top; F, northeastern till, containing crystalline bowlders. This section furnishes the only discovered evidence of two distinct glacial epochs. As no other section was found showing like or similar phenomena, little stress is laid upon this.

DEDUCTIONS FROM INTERRELATIONS.

AGE OF THE QUARTZITE GRAVELS.

As has been shown, the quartzite gravels are found on the plateaus that mark the earliest level of the plain next the mountains, on the slopes that lead to lower erosion plains, on the terraces above the present stream beds, and in the stream channels themselves. The topographic position of these gravels and their nature are such that they could not have been deposited by the ice which formed the existing moraines in the present mountain valleys. This is seen in their topographic relations, in the absence of glacial markings, in the absence of limestone and diorite bowlders, and in the great weathering to which they have been subjected. The till laid down by the mountain glaciers contains a large percentage of limestone bowlders, the glacial markings are distinct, and very little weathering has taken place. The gravels are found above the level reached by the ice in the mountain valleys and outside of the area covered by the Keewatin ice sheet or by the lake which existed in front of it. These facts prove that the gravels antedate the last Glacial epoch.

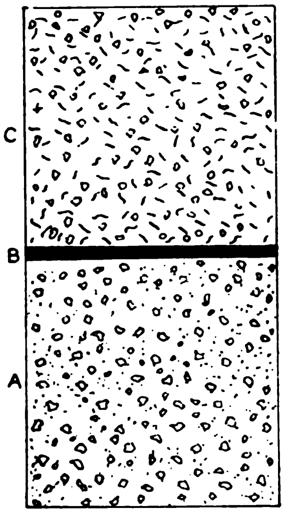


FIG. 31.—Section on Belly River within the terminal moraine of the Keewatin ice sheet. A, Till formed by Belly River Glacier, containing many bowlders, all of which are smoothed and striated to an unusual degree, 75 feet; B, soil, of which only a small exposure was seen, which contained no fossils; C, till formed by the Keewatin ice sheet, 80 feet.

The question of most importance is whether they are or are not of glacial origin. Were they deposited by earlier mountain glaciers or by an earlier Cordilleran ice sheet, or were they formed by streams? Dawson[a] is of the opinion that they are of glacial origin, and calls the formation the Albertan.

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[a] Dawson, G. M., Glacial deposits of southern Alberta: Bull. Geol. Soc. America vol. 7, pp. 39, 42, 54.

His description is as follows:

> Deposits of coarse gravels, often containing stones up to 6 inches in diameter, all well smoothed and waterworn, but often not perfectly rounded. They are generally arranged in rather tumultuous manner—that is, not in regular lines graded according to size, and with pebbles sometimes standing on end. The stones are chiefly Rocky Mountain quartzite, but a considerable number of pebbles of limestone from the same source are included. . . . Some of these gravels are striated. . . . The Saskatchewan gravels of the plains represent and gradually pass into a western bowlder clay in approaching the mountains.

The only bowlder clay seen along the eastern face of the mountains is that deposited by recent ice action, and none was found passing into the gravel formation. Those who have seen the great moraines and have observed their lakes, the freshness of their bowlders, the slight weathering and erosion to which the surface of the till has been subjected, and their general look of newness, would call them Wisconsin in age rather than Albertan.

As Dawson suggests, the gravels are older than any Keewatin drift found in the region. They are also older than any till deposited by mountain glaciers, and, as will be shown later, older even than the valleys now occupied by Milk River, Cutbank Creek, and Two Medicine River. The question of their origin is a troublesome one, but from a careful study of the formation south of the boundary line, they are believed to be not of glacial origin, but to have been deposited by streams in pre-Glacial time. In support of this interpretation there are the following reasons:

The gravels are waterworn and generally rounded. Their size is uniform over a great extent of country, though the pebbles found near the mountains are a little larger than those 20 miles out on the plains. From the forty-ninth parallel south there is a change in the character and position of these gravels which would suggest water deposition, for in each river basin the pebbles are similar to the rock exposed along the upper course of that particular river, though the varieties in the basins differ from one another. The pebbles, too, are wanting on some of the higher divides and buttes. An ice sheet of size sufficient to have covered the gravel area would have left a more heterogeneous deposit, and one covering the heights.

On the other hand, there seems to be no reason whatsoever for assuming them to be glacial. The question of the origin of these gravels was kept in mind during the entire summer, and the area covered by them was carefully worked over, but they show no marks of an ice-deposited formation. There are no glacial markings of any kind where they have not been affected by the ice of the later Glacial epoch. In no case is till associated with the gravel; nor is there ever a suggestion of terminal or ground moraine topography, though the gravels are found on tops of great plateaus, where any such formation would naturally have been preserved. Then, too, in regions where the moraines deposited by mountain ice contain limestone and other easily weathered rocks, the gravels are composed of only the most durable materials.

The valleys which have been developed in the drift are small; those which have cut into the plain since the gravels were deposited are very large. Two Medicine, Milk, and Sun rivers flow at the bottom of valleys which are in places 500 to 1,200 feet deep and 5 to 10 miles wide. Between these river valleys are flat plains covered with gravel formation, wide near the mountains, but toward the east gradually narrowing to a small ridge, and finally disappearing altogether. Where the slope is great the energy of the stream has been spent in downward cutting. Farther east, where the slope is less, the river has cut laterally and developed flood plains at the expense of the divides, which are of approximately the same height. There appears to be a slight slope to the southeast, which would indicate that the major streams responsible for this base-level flowed in that direction. The gravels must have been deposited before these great valleys were cut and at the time of the development of this first base-level, otherwise their position on isolated points could not be explained.

The date of the first base-leveling epoch has not been exactly determined. It must have occurred after the Cretaceous sea had retired from the region, and long enough before Glacial time for the development of the great river valleys which trench the western portion of the plains. This may carry it back into the Tertiary—perhaps to the end of the Miocene, for there are a few scattered Miocene deposits on some of the isolated high points which rise above the Canadian plains. This, too, would throw the date of the first base-level back far enough to give time for the erosion of the great valleys. If the base-level is referred to the Pliocene, it is hardly conceivable that Milk River and Cutbank valleys could have been eroded.

The distribution of the gravels resembles to a remarkable degree the distribution of the Lafayette formation in the east, though the relief of the underlying surface is much greater here. The various stages in the history of their deposition appears to have been as follows: Base-leveling in the later part of the Tertiary removed a great part of the Eocene and Miocene beds that are now exposed in a few isolated places in Canada and left the Cretaceous rocks exposed over a great plain stretching north and south along the face of the mountains. If then the mountains were slightly lifted while the plain was not, the streams would have been rejuvenated and the carrying out of the mountain material begun. At the foot of the mountains and at the border of the plain the velocity of the streams was checked and the material carried out deposited somewhat evenly over the surface, the coarser material near the mountains and the finer farther out. Next followed a rise of the whole region and the streams of the new cycles began to cut into the plain covered with the gravels from the mountains. As erosion went on, the gravels followed the streams both vertically and horizontally, tending all the while to become concentrated in the bottoms of the valleys and scattered eastward along the banks of the streams. While the gravels were descending from the upper plain to the lower terraces, gravels of the same sort were being brought out by mountain streams and mingled with those reworked from the older formations. At the time of the Glacial epoch the valley trains forming in front of the moraine contained not only bowlders marked and polished by the ice but also the gravels that had been lowered into the stream beds by lateral erosion and side wash. The original formation remains as it was first deposited only upon the old high levels. Below these high levels it has been augmented at all stages by the accession of material washed out from the mountains by streams of later times.

There seems to be one conclusion to be drawn from the nature, character, and position of these gravels, and that is that in their original form they are not a glacial or fluvial-glacial formation, but are of pre-Glacial age. On the lower levels material derived from the older formation is mingled with material carried out during and since Glacial time, segregated along the banks of the streams and covered by later drift deposits.

AGE OF THE NORTHEASTERN DRIFT.

The general opinion among geologists has been that the drift sheet of this area belonged to one of the earlier epochs of glaciation. Dawson correlates it with the "Iowan drift," the western extent of the Wisconsin being marked by the Missouri Coteau. Tyrrell calls it Kansan. On the Glacial map prepared by the United States Geological Survey this region is mapped as covered by Kansan drift.[a] The Wisconsin drift is represented only east of the Missouri Coteau and north of the forty-ninth parallel. In the light of recent studies, this correlation of the drift in the area under consideration is no longer tenable. The conclusion is held that the drift sheet under consideration was deposited by ice of the Wisconsin and probably of the late Wisconsin stage, this hypothesis being based on the newness of the region in terms of erosion, the sharply defined character of the terminal moraine, and the relation of the drift of the Keewatin sheet to that deposited by the mountain glaciers.

Evidence from erosion.—In order to discuss a question involving so many factors as the rate of erosion of a land surface, something besides the amount of weathering and trenching which have taken place must be considered. In the Montana region the post-Glacial cutting, with the exception of that accomplished by the large superimposed streams, has been slight; the lakes and marshes are still undrained; the till is weathered but a short distance from the surface, and the surface bowlders of the drift have suffered but little change.

The erosion along the moraine and the amount of weathering on its surface is about the same as that suffered by the drift of the Green Bay lobe in the vicinity of Baraboo, Wis. The following table shows the amount of rainfall for the last four years at Portage, Wis., and at Kipp, Mont., near the edge of the drift of the two regions:

Rainfall at points in Wisconsin and Montana, 1896-1899.

Locality.	1896.	1897.	1898.	1899.
Kipp	26.28	22.23	18.26	25.61
Portage	26.97	28.04	25.00	30.43

It will be seen from the table that while the average rainfall is greater at Portage the difference is not so great as to affect profoundly the amount of erosion. A factor favoring erosion at Kipp as compared with that at Portage is the concentration of rainfall at the former place. Other conditions being equal, a great amount of rainfall during a single shower will occasion greater erosion than the same amount distributed through a longer interval. From personal observation in both regions it may be said that the amount of water falling in the course of a few hours is much greater in Montana than in Wisconsin. When the amount of post-Glacial erosion and the number of undrained lakes and depressions are taken into account, the Montana drift edge appears as young as that in Wisconsin. The conditions for erosion are different in the two regions, but the difference has not favored either place in the final results.

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[a] Leverett, Frank, The Illinois glacial lobe: Mon. U. S. Geol. Survey, vol. 38, 1899, Pl. I. Upham, Warren, The Glacial Lake Agassiz: Mon. U. S. Geol. Survey, vol. 25, 1895, Pl. XVI.

The amount of weathering suffered by the bowlders and the upper surface of the drift is less in the Montana region than in Wisconsin. In Wisconsin the drift is leached of its soluble materials to a depth of from 2 to 3 feet. In Montana the average depth of the weathered zone is rather less. The bowlders in the former drift sheet are decomposed, in some cases, so badly that a blow of the hammer will shatter a granite bowlder a foot in diameter, while the bowlders in the drift of the western area are not decomposed to a great extent. On the other hand, mechanical agents of weathering, such as wind erosion (Pl. VII, *B*, p. 36) and the sudden changes of temperature, are active. On taking these various factors of erosion and weathering into consideration, it is thought that the age of the Montana drift can not be greater than that of Wisconsin.

Evidence from the topography of terminal moraine.—The edge of the Kansan drift sheet is generally attenuated. It is somewhat thickened in places and occasionally ridged, but is not usually marked by a definite terminal moraine. The edge of the Iowan formation is better marked, though in no place is it known to form a continuous or conspicuous ridge. The ice of the Wisconsin sheet alone appears to have produced the great terminal ridges which cover the country. In Dakota Prof. James E. Todd has described a series of these moraines which correspond roughly with the series found in Montana. The Dakota moraines are of Wisconsin age, and when these have been traced westward it may be found that they join those in Montana.. If sharp terminal topography counts for anything in the classification of drift sheets, the Montana moraine is of Wisconsin age.

Evidence from relations of the two drift sheets.—As has been shown, the Keewatin drift of this region is, at its edge at least, younger than the drift of the mountain glaciers. If any data could be obtained that would throw light upon the age of the latter, the relative age of the former might be assumed. Very little has been written concerning the age of the mountain drift, but the main portion has usually been assumed to belong to a late stage of the Glacial epoch. It is so mapped on the two plates to which reference has been made (p. 52, footnote). The drift deposits of Colorado, Wyoming, California, Utah, and Washington are supposed to be the work of glaciers belonging to a late epoch, the Wisconsin.

The moraines of Montana appear as young as those of these other States. Their fresh moraine topography, their lakes, and the little erosion to which they have been subjected all stamp them as young formations. In the mountain canyons the exposed rocks in situ still bear marks of the glaciers in the form of polishings, striations, and grooves. No long interval of time could have intervened since the last advance of the ice without the destruction of all marks of glacial action by weathering. Especially this would be true in a region where the work of the wind and sudden changes of temperature are ever active.

Granting that the mountain ice is of Wisconsin age, the Keewatin drift sheet must belong to the same Glacial epoch. The length of time that existed between the deposition of the till from the mountains and that laid down by the Keewatin sheet can not be told definitely by any field observations. The amount of erosion to which the two drift sheets have been subjected is the same so far as field studies show. The agents of weathering have attacked the surface of the till and the bowlders to about the same extent in each drift sheet. Where the two sheets of drift are found side by side, as in the St. Mary basin, it would be difficult to tell their relative ages from any topographic feature.

The ice from the mountains and from the Keewatin centers may have been formed by the same climatic episode. The ice in the mountain valleys may have pushed out upon the plain, deposited its moraines, and then, not being of large extent and hence being easily and quickly affected by climatic changes, may have withdrawn promptly at the beginning of adverse climatic conditions. The continental ice sheet, on the other hand, with its vast dimensions and its center far to the north, may have continued to push outward for some time after adverse conditions on its extreme southwestern border had set in, and hence may have invaded the area of the more local drift after the mountain glaciers retired. The general conclusion is that the two drift sheets were formed during the same ice epoch, and that where they overlap they were deposited within a short period of each other.

THE DRIFT OUTSIDE OF THE TERMINAL MORAINE.

Beyond the terminal moraine the glacial deposits are of two kinds—scattered bowlders with till, or a thin till sheet, grading at the edge into a bowldery area. The edge of this till sheet is in some places marked by a slight ridge that resembles a terminal moraine in a feeble state of development. More often there is no definite ridge, but a rolling country, covered with shallow lakes and lake basins, which frequently gives place to a simple thinning out of the till sheet, with no evidence of either a terminal ridge or of ground-moraine topography.

The bowlders are scattered over areas that were once covered by Glacial lakes. These lakes have already been described as existing along the western margin of the ice edge in two separate basins, and also south of the ice sheet in the valley of the Missouri. That these bowlders were deposited in lakes is evident from the fact that in each small valley tributary to the main basin the bowlders are found at the same general level above the river. In many cases the level of the old lake may be followed for miles around the head of a valley, every few rods being marked by a deposit of one or more bowlders of northeastern origin. The bowlders are most numerous along the shores of the lake, where floating ice grounded. Over the bottom of the valley such deposits are fewer and more scattered. Near the border of the lake an ice floe or iceberg carrying morainic material would strike the shore and remain there until it was entirely melted, leaving its deposit in a small heap near the old shore line. In some of the smaller valleys, distant from the ice edge, instead of a regular line of bowlders two or three small bowlder piles were found. Over the bottom of the lake there are few such piles, the material having apparently been dropped a little at a time as the ice drifted over the surface. The bowlders are more numerous on the eastern valley slope than on the western, and decrease in number with increase of distance from the ice edge. Around the inlet of these lakes, where the currents made by the entering rivers were strong, few or no bowlders are found. They are most numerous along the outlet.

The thin sheet of drift is present at various places along the ice edge. In the vicinity of Great Falls there is a large area of the deposit, which grades into the bowlder belt. North of the Highwoods the same formation is found. In the valley of the Musselshell and on the north bank of the Missouri opposite the mouth of the former river, a formation occurs which may have been deposited either by ice or by water. The edge of this deposit has not been completely mapped, and sufficient field work has not been done to determine its nature. On the map the edge that has been traced is marked by a full line, while the dotted line marks the supposed position of the part not yet surveyed.

The fact that there is such a border of drift without the terminal moraine suggests two different ice epochs, but very little was found in the field to support this theory.

The material of the ground moraine within the terminal moraine does not differ essentially from the material in the till sheet which borders it. The bowlders are of the same variety, and exist in the same proportion. A limestone is equally abundant and equally weathered on both sheets. No embedded soil or other evidence of interglacial phenomena is found, although unusual opportunity was offered both for its preservation and its discovery. The till in many places rests upon a bed of pre-Glacial gravels in such a way that not a stone seems to have been disturbed or removed by the ice. Certainly ice that passed so lightly over a gravel surface would not destroy evidence of old soil or other indications of an interglacial period.

Excellent opportunities were offered for studying sections of the drift at and within the terminal moraine. The Missouri has exposed sections of the drift 200 feet thick. The Great Northern cut-off near Fort Benton has exposed sections that clearly show drift from bed rock to the top of a 250-foot exposure, but in no section was there any suggestion of an interglacial period.

The evidence in favor of the existence of two distinct till sheets is also not convincing. The relation of the terminal moraine to the border of the thin drift is such as to suggest the pushing in of the ice after the deposit of the first sheet. In other words, the moraine appears to be later rather than recessional. This relation is shown on the map (p. 30). If the moraines were recessional, one would expect a thin border fronting the moraine at all points instead of occurring only here and there along the edge. The fact that there is more erosion in the thin than in the thicker drift ought to be indicative of their respective ages. Along the Missouri, between the mouth of the Highwood and the mouth of Little Sandy, 27 coulees of size large enough to be mapped are found. Seven of these come in from the north, or from the area of the thick drift, and 20 from the south, or from the area of the thin drift sheet. It is probable, though, that the greater amount of erosion in this area may be accounted for by the fact that there is greater drainage from this direction on account of the presence of the mountains south of the drift border.

SUMMARY.

The Keewatin ice sheet covered the northern part of Montana east of the Rocky Mountains and extended south to the Highwood Mountains and into the valley of Musselshell River. The point where the meridian 113° 15′ crosses the forty-ninth parallel marked its westernmost extent in the United States. North of the boundary line, in Alberta, the drift is found still farther west. Its southern edge was lobate in form, the lobation being due to the presence of the Highwood, Bearpaw, and Little Rocky mountains, which retarded the forward progress of the ice while the great valleys between them allowed it to move farther south.

The Sweetgrass Hills, just south of the Canadian line and about 30 miles back from the edge of the ice, were not covered, but stood as three great nunataks, the highest reaching 2,000 feet above the ice surface.

From data gathered here and at the edge of the drift, it was found that the average slope of the glacier must have been about 50 feet per mile. Wherever, along the sides of various valleys, measurements could be taken, it was found that the slopes of the surface had been slight.

Along the Rocky Mountains glaciers issued from the valleys and deployed upon the plain to the east. The moraines of 14 of these glaciers were traced and mapped. In a number of cases, the ice from several mountain valleys had united and formed piedmont glaciers. The ice from a single mountain valley seldom reached far out on the plain, but the piedmont glaciers extended many miles from the foot of the mountains. This was especially true of the Blackfoot Glacier, formed by the union of the Two Medicine, Birch Creek, Blacktail, and Whitetail glaciers. This sheet of ice extended 35 miles from the foot of the mountains, measuring in its widest part over 30 miles. Each glacier deposited at its edge a very well defined moraine, characterized in general by bowlders peculiar to the mountain valley from which the ice issued. These moraines were in places 200 feet high and often a mile or more wide.

The basins of four large rivers—the St. Mary, Two Medicine, Teton, and Missouri—were dammed by the ice and the drift of the Keewatin ice sheet. The result was the formation of extensive lakes in the river basins west of the ice. These lakes can be divided into two classes—those formed in front of the ice itself and those formed in front of the drift dam. The former were large and existed only while the ice was present. The latter were more restricted in size but were more permanent, remaining until the drift dam had been cut through. The deposits made by the first lakes consisted largely of bowlders carried out by floating ice. The deposits in the smaller and later lakes were clays and gravels brought in by the rivers. The largest of these bodies of water was caused by the damming of the Missouri.

Just south of the forty-ninth parallel, between the meridians 113° 10′ and 113° 15′, the till of the Keewatin ice sheet and that of the mountain glaciers overlap. At no other point south of the boundary line did ice from opposite directions occupy the same territory, but in Two Medicine Valley the ice from the east advanced to within 2 miles of the position occupied by the ice from the mountains.

The Keewatin sheet reached its most advanced position after the valley glaciers from the west had retreated, for the drift of the former overlies the drift of the latter at various points both north and south of the national boundary. In some cases the till from the northeast overlies the till of the mountain glaciers. This is true in the St. Mary Valley, as mentioned above, and also in the valleys of St.Mary River, Belly River, and Lees Creek. In other places till from the east overlies fluviatile deposits that are connected with the western drift, but extend down the valleys several miles beyond the ends of the mountain glaciers. Again, we find that lake and berg deposits, having their sources in the northeastern ice, overlie the till left at an earlier time by the mountain glaciers.

It is believed at the present time that as many as five separate ice sheets covered the northern part of the United States. These, named in chronologic order, are as follows: (1) Sub-Aftonian, (2) Kansan, (3) Illinoian, (4) Iowan, (5) Wisconsin. The drift deposits formed by the mountain glaciers belong to a late epoch. They are certainly not earlier than the Iowan and are probably as recent as the Wisconsin. So far as can be shown by the evidence gathered, no great period of time elapsed between the deposition of the Rocky Mountain drift and the deposition of the Keewatin drift. Beyond the edge of the Wisconsin drift sheet is one somewhat older, though the data obtained in the region covered were not sufficient to determine its age.

In the region between the two drift deposits, there is, on the high divides between the rivers, on the terraces along the flood plains, and in the stream beds, a curious formation which has been called the quartzite gravels. They are composed of resistant quartzite and slate and contain no limestone or other less durable rock. Though waterworn, they show no signs of glaciation. From their topographic position and from their character it was concluded that they were deposited by streams flowing over a flat plain. This deposit occurred along the eastern front of the mountains and extended out from them many miles. Subsequently the land was raised, great valleys were cut into the old base-level, and the quartzite gravels were lowered upon the terraces and scattered still farther eastward along the courses of the revived rivers. The base-level probably occurred in the latter part of the Tertiary. and the gravels date from that time. When the Keewatin ice advanced into the region, many of these gravels were picked up, glaciated, and deposited in the under portion of the drift sheet. They are undoubtedly the Saskatchewan gravels of the Canadian geologists, by whom, because of their weathered appearance, their glacial markings, and their position at the bottom of a young drift sheet, they were classed as an earlier glacial deposit—the Albertan. It seems necessary now to reject the Albertan, and to class these gravels not as an old glacial deposit, but simply as old river gravels incorporated in a later drift.

As a result of the deposition of drift of the mountain glaciers, there were minor changes in drainage. Streams were shifted from one side of the valley to the other and their slope was modified. More marked were the changes effected by the Keewatin ice. The Shonkin Sag was developed by ponded glacial waters. The Teton River was shifted from its old valley into the valley of the Missouri and minor changes were produced in the courses of Two Medicine River, Birch Creek, Cutbank Creek, and St. Mary River. Missouri River was turned from its course at a number of places, causing the falls in the river near the city of Great Falls and the rapids and narrows in other parts of its course. This ice sheet also undoubtedly turned the Missouri from a northern course and made it tributary to the Mississippi River.

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